PROMOTION OF POWER GENERATION FROM SOLAR ROOFTOP IN THAILAND

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**A Dissertation Submitted in Partial
Fulfillment of the Requirements for the Degree of
Doctor of Philosophy (Environmental Management)
The Graduate School of Environmental Development Administration
National Institute of Development Administration
2020**

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ABSTRACT

Title of Dissertation	PROMOTION OF POWER GENERATION FROM SOLAR ROOFTOP IN THAILAND
Author	Supawadee Nusin
Degree	Doctor of Philosophy (Environmental Management)
Year	2020

This study investigated the factors that promote current power generation from solar rooftop, analyzed the factors influencing the expansion of solar power generation not registered with government agencies, and recommended a model to promote sustainable power generation from solar rooftop. The study consisted of qualitative research utilizing Delphi technics and data analysis based on the framework of CIPP-I model consisting of data analysis of the expansion of solar power generation drawn from the import volume of solar panels (trade database of Ministry of Commerce and Customs Department between 2002-2019) to build data on the current state of Thailand's solar power generation. In addition, a SWOT analysis for the promotion and analysis of the strategies that promote power generation from solar rooftop utilizing TOWS Matrix was conducted in order to develop a model of operation that promotes sustainable power generation from solar rooftop.

The findings revealed that the factors impacting the promotion of power generation from solar rooftop based on the framework of the CIPP-I Model were as follows. (1) Context consisting of demand for electricity in urban areas/growth of cities and towns/urban population, electricity price/oil price, opposition to new power plant, solar equipment becomes cheaper/through advancement in technology, rich exposure to solar light, and Alternative Energy Development Plan/policies/laws/regulations/ incentives. (2) Input consisting of social innovation/awareness/understanding, household's participation, solar equipment supplies/equipment quality assurance, and certification of equipment standards/ certification of private installer personnel-skill training. (3) Process consisting of grid code control electricity stability/power bank system, MEA/PEA facilitation of smart grid, and control of power ripple/fluctuation (surge/drop)/data collection/data processing/system self-correction. (4) Product/ Outcome consisting of amplification of production of solar electricity, increased share of

renewable clean electricity, increased power generation efficiency, and reduced power loss. (5) Impact consisting of economic impact: increased economy of scale; social impact: reduced needs for new power plant, increased employment, power stability/diversification, good image/clean environment/gaining public appreciation and acceptance; and environmental impact: use of solar light found everywhere for power generation.

The findings regarding the expansion of solar power generation not registered with authorities revealed that, in Thailand, the cumulative solar cell installed capacity totaled 46,478 MW with an average annual growth rate of 37%. Those registered for solar power generation equaled 2,935.019 MW (Office of Energy Regulatory Commission, 2020). Export of solar cells between 2007-2019 totaled 2,315.98 MW (Customs Department, 2020). The analysis of policies, strategies, and plans relevant to the promotion of power generation from solar rooftop revealed that, in the past, the government formulated plans and policies to promote solar power generation but lacked a clear timeframe for determining production goals. The policies also lacked continuity, integration, and cooperation among relevant agencies. As a result, the promotion had little success. The findings underwent a SWOT analysis and TOWS Matrix, respectively. The analysis revealed that the model to promote power generation from solar rooftop consisted of three processes as follows. (1) Policy consisting of formulation of an action plan based on policies to promote power generation from solar rooftop with participation of stakeholders and determination of clear processes of electricity generation for own consumption or purchase/sale under supervision of government agencies. (2) Promotion consisting of memorandums of agreement with responsible agencies establishing a body for long-term research and development of sustainable technology for solar power generation, establishing an information center and one stop service for power generation from solar rooftop, and establishing an office for the development of the system management of power generation from solar rooftop through participation of all involved sectors. (3) Management and supervision consisting of measures to promote the public's access to equipment for power generation from solar rooftop; establishing an ad-hoc agency to be responsible for the control of system installation that meets the requisite standards; cooperation with Professional Qualification Institute; review of relevant laws, rules, and regulations for concrete promotion of power generation from solar rooftop; and establishment of an agency responsible for the management and control of the disposal of solar panel waste.

ACKNOWLEDGEMENTS

The thesis entitled promotion of power generation from solar rooftop in Thailand would not have come to the successful completion without the valuable guidance of my advisors Professor Dr. Wisakha Phoochinda and Associate Professor Dr. Sompote Kunnoot. I would like to extend my heartfelt gratitude for their extremely valuable comments and their dedicated efforts for the improvement of this thesis. I would also like to take this opportunity to extend my gratitude to Associate Professor Dr. Kraichat Tantrakarnapa as Chairman and Member of the Thesis Examination Committee for his most insightful advice to enhance the quality of this thesis.

I would like to express my profound thanks to the experts who investigated the questionnaire and provided their opinions on promotion of power generation from solar rooftop in Thailand for the completeness of the model.

My foremost gratitude and enormous indebtedness are extended to the lecturers of the Program in Environmental Management whose immense knowledge have greatly benefited this thesis. My special thanks are also extended to all the staff for their continuous support.

On a final note, I would like to extend my grateful thanks to my family and friends for their unwavering encouragement and support so that this thesis has met with successful accomplishment.

Supawadee Nusin

March 2021

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CHAPTER 1

INTRODUCTION

1.1 Statement of the Problems

Energy is a necessity for daily human life. It is essential for the generation of lighting and heating, underpinning economic prosperity, as well as to support transport, industry, and agriculture, among many other functions. According to World Energy Outlook 2018, global demand for energy will increase 1.3% a year until 2040 (International Energy Agency, 2018). At the same time, there has been global awareness of energy consumption by placing importance on development of new technologies for low carbon energy. As a consequence, renewable energy such as solar energy, wind energy, hydropower, and geothermal energy, has assumed an important role in energy development because, unlike non-renewable sources such as coal, it is inexhaustible. The IEA forecast that the consumption of renewable energy for power generation will increase approximately 7% a year over the next two decades. In 2040, the global consumption of fossil-based energy (petroleum and other liquid fuel, natural gas, and coal) and nuclear will constitute the highest share of 83%, followed by renewable energy (wind energy, solar energy, and geothermal energy) with 9%, and hydropower with 8% (US Energy Information Administration, 2017).

In 2020, Thailand’s demand for nearly all types of energy decreased while the demand for renewable energy increased 0.4% and the consumption of imported electricity increased 7.1%. This was because at the end of 2019, three hydropower plants in Lao PDR began distributing electricity into the system (Energy Policy and Planning Office, 2021). Supply or production of energy is therefore important to respond to the needs of consumption, national development, and economic development. Thailand uses natural gas as the main source of energy for power generation at 58.95% (Electricity Generating Authority of Thailand, 2021), but fuel from natural gas sources in Myanmar is still imported. The situation remains uncertain as problems in the supply and transport of natural gas may have a wide impact in terms of power failure and damage to the business and industrial sectors, as well as people's daily life.

Therefore, the public sector has been formulating the policy to promote the increased use of alternative energy in the country by assigning the Ministry of Energy to devise the draft Alternative Energy Development Plan 2018-2037 (AEDP2018), which consists of the Energy Efficiency Plan 2015-2036 (EEP 2015), to determine the framework and direction of the national development of alternative energy. The mixed measures consist of the "Push" factors with the supervisory measures through Energy Conservation Promotion Act B.E. 2535 (1992) and the amended Energy Conservation Promotion Act B.E. 2550 (2007) in parallel with the "Pull" factors or financial measures through the support and assistance from the Energy Conservation Promotion Fund and the Power Development Plan 2018-2037 (PDP2018). At the end of PDP2018 or at the end of 2037, the power capacity in the power generation system to the three electricity units including EGAT, Provincial Electricity Authority (PEA), and Metropolitan Electricity Authority (MEA) will total 77,211 MW with development of transmission lines nationwide. Power generation from solar rooftop of residences, business buildings, and factories is part of the drive to reach the PDP2018 objectives. In the past, the government supported solar rooftop power generation with incentive measures such as Adder costs at the end of 2006 and feed-in tariff (FiT) as the supporting measure to purchase power from renewable energy with special rates in 2013 to accelerate investment in power generation with alternative energy technology under the operation of PEA and MEA. Solar power generation with 2,935.019 MW was registered (Office of Energy Regulatory Commission, 2020). Concurrently, foreign countries have also formulated policies to promote solar power generation. For example, India formulated the policy to promote solar power generation in 2019 with the capacity of 34,831.384 MW. Japan's capacity at that time was 61,840 MW, and Australia's capacity was 15,928 MW (International Renewable Energy Agency, 2020).

However, the reliance on the solar power generation requires that a survey be conducted of the roof structure and surrounding environment, geographical features of the areas of installation, and the climate of the particular area before installation and operation. Therefore, the structure is designed for appropriate installation of solar power generation for the maximum efficiency of power generation (Broderick, Albert, Pearson, Kimerling, & Michel, 2015). With different geographies and climates, solar cells produce different volumes of electricity. For example, the assessment of solar power generation in India yielded thermal efficiency depending on climate and model of installation system (Tiwari, Sodha, Chandra, & Joshi, 2006). Thailand is located between 6-10th parallel north and receives sunshine at the yearly average of approximately 4-5 kilowatts-hour/square meter/day. If the light receiving areas can be adapted to follow sunlight throughout the day, it is expected to receive sunshine at approximately 1.3-1.5 fold (Phatiphat ThounThong, 2009). Solar power generation has higher production costs than other fuels, and there must be a transmission line network facilitating system in order to operate the project. For example, in Pakistan, there is demand for solar development but the present transmission line network is not appropriate and therefore not operational (Mirza, Maroto-Valer, & Ahmad, 2003). The installation of solar rooftop is limited by budget as investment in installation systems and maintenance costs are high. Therefore, some areas cannot afford to purchase solar cells (Kar, Sharma, & Roy, 2016). In Nepal, which faces a high shortage of energy, it is necessary to import fossil fuels and electricity. Solar rooftop can therefore help mitigate the country’s power failures but there are limitations due to high technology costs and lack of government support (Gautam, Li, & Ru, 2015). UAE also faces problems with financial support for solar power generation, which is low compared to non-renewable energy sources (Singh & Banerjee, 2016). Moreover, in Santa Monica, California, US, solar rooftops are installed to reduce the carbon dioxide emission as set by the emission reduction wedges for California for 2050, but they face numerous problems in terms of rules and regulations for the installation of solar rooftops (Malone, 2016). These limitations obstruct the promotion of solar power generation abroad.

For Thailand, in the past, there were obstacles in terms of management particularly regarding the announcement of the plan to buy electricity, submission of application form, and request for permit based on regulations, as there were numerous legal requirements and agencies involved in the operation. The study of the development of solar rooftop power generation in Thailand by Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) in 2014 revealed that the management in the past faced many problems as follows: management of permit process; connection with transmission system that did not facilitate the development of solar power generation; the communication between entrepreneurs and government agencies took too much time; the request process was still unclear; confusion regarding sequences and regulations before each process of operation; uncertainties in the plan to buy electricity, therefore losing the readiness to participate in the project; the duration of the project operation was too short so no project could finish on time; submission of application form to power supply agencies (PEA/MEA) whereby it was necessary to submit the application form to participate in the project in person; the selection of applicants with different practices from what was determined by law; management and request for permit based on regulations such as permit to modify buildings and certification of power adapters delaying the project; as well as many legal requirements and relevant agencies that created obstacles to the operation of the project.

Solar rooftop power generation would reduce electricity bills for households as solar energy could be transformed into electricity. The installation would to make effective use of the rooftop space, which is different from solar farm which requires large areas for system installation. Investment in solar rooftop power generation would cost less than solar farm due to low installed capacity. It was found that most residential houses installed solar rooftop power generation with the highest rate of 9-10 kilowatts. In contrast, for solar power generation installed on the ground, the system installation was upwards from 1 MW (Department of Alternative Energy Development and Efficiency, 2017c) which required high investment for system installation. Therefore, businesses were solar farm installers while the general public were solar rooftop installers.

Therefore, to support future solar power generation in response to the needs to reduce the energy consumption of households, businesses, and industries, and others to reduce pollution in the environment and promote the country's energy security, the researcher studied the factors that currently promote solar rooftop power generation as well as studied the expansion of solar power not registered with government agencies. Based on the trade database of Ministry of Commerce and Customs Department, Thailand's solar power generation between 2002-2019 had a total solar cell installation capacity of 46,478 MW. However, those registered for solar power generation in the system was a mere 2,935.019 MW (Office of Energy Regulatory Commission, 2020).

This is an important issue requiring analysis to establish the cause for the low figure and develop a guideline to promote more registrations, determine the current situation of solar power generation in Thailand, and formulate a management plan for the country's efficient energy management.

The study conducted via a SWOT Analysis and TOWS Matrix in order to formulate the model to promote solar rooftop power generation in the future. The review of solar rooftop installation in Thailand by Chulalongkorn University revealed that the factors impacting power generation included the intensity of appropriate solar radiation and development policy of renewable energy. Moreover, it remains necessary to have financial support/support from the government so that power generation from solar energy can compete with other forms of power generation. Thanapol Tantisattayakul (2015) evaluated the financial support measures for solar rooftop power generations of residences in Thailand and revealed that the installation of solar PV rooftop was not cost effective in terms of system cost per average installed capacity. The installation would be cost effective when the installers had a system cost per installed capacity not exceeding 71 baht/W.

In addition, Aksornchan Chaianong, Athikom Bangviwat, and Christoph Menke (2019) study of rooftop PV adoption in Thailand revealed that a lack of a grid system able to accommodate power generation from renewable energy remained a major obstacle. One major factor receiving the general public's acceptance was the cost in installation payback period. The purchase of solar power was also an important motivation. Kangsadan Sagulpongmalee and Apichit Therdyothin (2016) evaluated photovoltaic system feed-in tariff models in Thailand and found that the purchase of electricity through the feed-in tariff measure could attract more investors for solar rooftop power generation and must be operated in conjunction with other financial support measures such as low interest loans and tax incentives. However, there has been no study of the expansion of solar power generation outside the registration system despite the country's energy management requiring this data of the total amount of electricity produced to plan power generation and determine the total amount of backup electricity. Moreover, when rooftop solar panels expire, disposal is required so as not to impact the environment. If the growth of solar power generation is registered, it would also be possible to forecast the amount of waste to be disposed of when it expires and thus be able to plan for its appropriate disposal. In this study, the researcher conducted a data analysis of the factors that promote solar rooftop power generation and the expansion of solar power generation outside the system to utilize the data to produce a model to promote solar rooftop power generation in the future. It is hoped that as a result there will be more solar rooftop power generation and producers of solar energy will be attracted to register with government agencies or generate solar power within the system with understanding of the connection between strengths, weaknesses, opportunities, and obstacles of power generation in Thailand. This would contribute to the country meeting Sustainable Development Goal (SDG) Goal 7, the guarantee to ensure access to affordable, reliable, sustainable, and modern energy for all.

This study can be used to promote solar rooftop power generation in the future as an efficient alternative energy. In addition, solar rooftop is an alternative for energy consumption and electricity security that users in various regions can be confident in, adding to the stability of Thailand's electric power system.

1.2 Research Questions

1) What are the factors that promote solar rooftop power generation?

2) What is the expansion of the solar power generation by solar rooftop not registered with government agencies?

3) What should be the model to promote solar rooftop power generation in Thailand?

1.3 Research Objectives

1) Study the factors that promote solar rooftop power generation.

2) Study the expansion of solar power generation by solar rooftop not registered with government agencies.

3) Present the model to support sustainable solar rooftop power generation.

1.4 Expected Benefits

1) Outputs

(1) Determine the factors that promote the current solar rooftop power generation.

(2) Determine the expansion of solar power not registered with government agencies.

(3) Construct a model to support sustainable solar rooftop power generation.

2) Outcomes

(1) Thailand's electricity users have a choice to consume secure and stable electric power.

(2) Policy developers such as the Department of Alternative Energy Development and Efficiency can more effectively formulate policy to promote solar rooftop power generation.

(3) Implementing agencies such as MEA and PEA may more effectively accommodate smart grid to those who install solar rooftop power generation system.

3) Impacts

(1) Data to promote solar rooftop power generation.

(2) Increased solar rooftop power generation.

1.5 Scope of the Study

1) Scope of content

This study focused on the factors that promote solar rooftop power generation in Thailand and the expansion of solar power generation outside the system.

2) Scope of area and population

Information was compiled from executives of EGAT and those involved in the project to generate power from solar rooftop of PEA, MEA, residences, business buildings, and factories installed with solar rooftop who participated in the project and sold electricity to EGAT, as well as the information of Thailand's import of solar cells.

3) Scope of duration

Information was compiled for a duration of two years (1 January 2018 – 31 December 2019).

1.6 Definitions

Solar rooftop power generation means solar rooftop power generation for residences, business buildings, and factories under the operation of PEA and MEA and sell electricity to electricity agencies.

Solar rooftop means system of power generation that can be installed for residences, office buildings, factories, or garage roofs and can generate power for use in conjunction with the formal distribution system (registration).

Factors to promote solar rooftop power generation means factors which facilitate solar rooftop power generation in the context, input, process, output/outcome, and impact.

Solar power not registered with government agencies means those who install solar rooftop power generation system for own usage and are not registered with government agencies or other such bodies.

Expansion means current growth of Thailand's solar power generation.

Model means methods to promote solar rooftop power generation and the construction of a model to promote solar power generation in the future.

CHAPTER 2

RELEVANT CONCEPTS, THEORIES, AND RESEARCH

The relevant concepts, theories, and previous research used as a guideline and foundation underpinning this research consisted of the following topics:

1) Relevant plans, policies, and strategies
2) Thailand's power generation system
3) Solar rooftop technology
4) Theories of project evaluation
5) Theories of SWOT analysis and TOWS Matrix
6) Patterns to promote solar rooftop power generation
7) Previous research

2.1 Relevant Plans, Policies, and Strategies

2.1.1 Energy Efficiency Plan 2015-2036 (EEP 2015)

Based on the forecast of oil prices in the global market remaining lower than 50 USD per barrel, the Ministry of Energy intensified the drive toward the energy preservation plan. It modified the former plan (2011-2030) for more appropriateness. It continued to use the mixed measures of Push with supervisory measures through the Energy Conservation Promotion Act B.E. 2535 (1992) and the amended Act B.E. 2550 (2007) in parallel with the Pull or financial measures through the support and assistance from the Energy Conservation Promotion Fund.

Based on the 34 measures to increase efficient consumption of energy, apart from the government's main policy to cancel/review the price subsidies of energy in order to send the signal to consumers to be aware that the prices were in line with the market mechanism, the Ministry of Energy operated in four economic sectors, namely: (1) industrial sector; (2) business buildings, government buildings; (3) residences; and (4) transport sector. It modified the direction of the policy through the measures based on empirical results to follow three strategies, namely: (1) Compulsory Program, (2) Voluntary Program, and (3) Complementary Program. The aim was to reach the goal as set in the policy to reduce the level of energy consumption by 30% in 2036 compared to 2010, equivalent to a reduction of approximately 56,142 ktoe (Ministry of Energy, 2015a)

2.1.2 Alternative Energy Development Plan 2015-2036 (AEDP 2015)

The development of alternative energy is part of the formulation of a consistent overall energy policy integrated with other energy plans. In formulating AEDP 2015, the forecast for demand of the final energy according to Energy Efficiency Plan (EEP 2015), in the case it can achieve the goal of reducing energy consumption by 30% in 2036 compared to 2010, the forecast of the demand of final energy in 2036 will be 131,000 ktoe. The forecast of the demand of net electric power of the country from Thailand's Power Development Plan (PDP2015) in 2013 was 326,119 million units or 27,789 ktoe. The forecast of the demand of thermal energy in 2036 equals 68,413 ktoe. The forecast of the demand for fuel in the transport sector from the fuel management plan in 2036 equals 34,798 ktoe. These serve as a framework to determine the goal to increase the share of the consumption of alternative energy, as well as consideration of the potential of alternative energy that can be developed, including electric power, thermal power, and biofuel under the AEDP 2015 with a share of 30% of the consumption of final energy in 2036 (Ministry of Energy, 2015b).

2.1.3 Master Plan of Thailand Smart Grid Development 2015-2036

In view of development focused on upgrading the electricity system (Smart System), upgrading service quality of electricity users (Smart Life), and upgrading the structure of electricity system that is environmental-friendly (Green Society), Ministry of Energy announced the Master Plan of Thailand Smart Grid Development 2015-2036 to determine the framework for the development of the overall Smart Grid network system. Smart Grid is the efficient management system for the consumption of electricity through Information Technology. The Smart Grid will calculate the electricity production capacity from fossil fuels and alternative energy and distribute it in line with the real usage because after production, electricity must be used immediately. Storage entails high costs.

The current system is designed with the aim of transmitting electric power from large power plants to users. The electric power flows in one direction with limited cooperation between automatic tools. In the future, the system will change into the Smart Grid which will accommodate distributed power generation and include renewable energy technologies such as solar energy, wind energy, and so forth. Electricity will be able to flow in two directions. Exchange of information can also flow in two directions. Power consumers have a role in power generation (Prosumer). Power consumers are provided the opportunity to use energy appropriate to their way of life and behavior for efficient consumption of power. A great deal of information is exchanged between tools. There is cooperation between processors, automatic equipment, and communication equipment (Energy Policy and Planning Office, 2015).

2.1.4 Policy to Promote Solar Rooftop Power Generation

In the past, the government formulated the policy to promote power generation from solar energy to attract investors using the Adder measure, then shifted to FiT according to the market mechanism of the reduced prices for solar panels according to the following:

1) Policy to purchase electricity from renewable energy with the Adder system

The Adder system was announced at the end of 2006. The government bought electricity at the same rate as Adder according to the type of RE, combined with the normal rate of electricity purchase which varied according to the costs of the country’s overall power generation which tended to increase. It attracted many investors to invest in RE in the first 3 years after the announcement of the Adder system (2007-2009).

Table 2.1 Incremental Rate of Adder Power Purchasing Prices, Improved on 9 March 2008

Energy	Old incremental rate (baht/kWh)	New incremental rate (baht/kWh)	Special incremental rate* (baht/kWh)	Support Period (Year)	Note
1. Biomass					
Install Capacity ≤ 1 MW	0.3	0.5	1	7	
Install Capacity >1 MW	0.3	0.3	1	7	
2. Biogas					
Install Capacity ≤ 1 MW	0.3	0.5	1	7	Incremental Promote small project
Install Capacity > 1 MW	0.3	0.3	1	7	
3. Waste (Non-hazardous waste and non-organic waste)					
Fermentation or landfill	2.5	2.5	1	7	Incremental due to costs for waste separation
Thermal energy	2.5	3.5	1	7	
4. Wind Energy					
Install Capacity ≤ 50 kW	3.5	4.5	1.5	10	Incremental to promote technological development in the country
Install Capacity > 50 kW	3.5	3.5	1.5	10	
5. Small Hydro					
Install Capacity 50-200 kW	0.4	0.8	1	7	Incremental to promote forest preservation and technological development
Install Capacity < 50 kW	0.8	1.5	1	7	
6. Solar	8	8	1.5	10	

Source: Energy Policy and Planning Office (2015).

2) Policy of power purchase from renewable energy with feed-in tariff measure

Feed-in tariff (FiT) is the measure that promotes power purchasing from renewable energy and thus attract the private sector to invest in renewable energy (as power generation from renewable energy has relatively high costs). FiT is power purchase at a constant rate throughout the project. FiT will not change with basic electricity fees and FiT enables clear prices.

FiT has long-term contracts between 15-25 years. The policy is used in many countries such as Algeria, Australia, Austria, Belgium, Brazil, Canada, China, Cyprus, Czech Republic, Denmark, Estonia, France, Germany, Greece, Hungary, Iran, Ireland, Israel, Italy, Kenya, South Korea, Lithuania, Luxembourg, the Netherlands, Portugal, South Africa, Spain, Switzerland, Tanzania, and Turkey. Thailand used the FiT measure in 2006 by making additional payments to power producers for renewable energy at different rates based on the type of technology used as shown in Table 2.2.

Table 2.2 Supporting Program Feed-In-Tariff (FiT) for Very Small Power Producer (VSPP) 2015

Power purchasing rate based on FiT as announced for use in 2015: for VSPP natural energy group			
MW	FIT (baht/unit)	Supporting duration (year)	FIT Premium (baht/unit) for projects in southern border provinces* (throughout project)
Hydro power			
Installed capacity ≤ 200 KW	6.90	20 years	0.50
Wind power			
All sizes	6.06	20 years	0.50
Solar energy			
On rooftop installed capacity 0-10 kWp	6.85	25 years	0.50
On rooftop installed capacity > 10-250 kWp	6.60	25 years	0.50
On rooftop installed capacity >250-1,000 kWp	6.01	25 years	0.50
On the ground all sizes	5.66	25 years	0.50

Note: *Projects in Yala, Pattani, Narathiwat and four districts in Songkla, namely: Chana district, Thepha district, Saba Yoi district, and Na Thawi district.

Source: Energy Policy and Planning Office (2015).

According to the Adder purchasing rate, the purchasing price of 8 baht/unit for the duration of 10 years led to a significant rise in the number of solar power producers. However, they gradually decreased when the government shifted to the support of FiT for the purchasing prices of residences ≤ 10 kWp 6.85 baht/unit, business/factories >10-250 kWp 6.40 baht/unit, and business/factories >250-1,000 kWp 6.01 baht/unit for the duration of 25 years. This shows that the purchasing prices and long-term purchase agreement is an incentive that affects the promotion of solar rooftop power generation.

The study of Thailand's power generation system revealed the roles and duties of agencies responsible for electricity transmission and distribution systems and the processes of license request for installation of solar rooftop power generation. As a consequence, the researcher could design a model to promote solar power generation which would be appropriate and congruent with Thailand's power generation system structure.

2.2 Thailand's Power Generation System

Thailand's power generation consists of three parts, namely: (1) electricity generation, (2) electricity transmission, and (3) electricity sale as shown in Figure 2.2. Thailand's power generation is mainly operated by EGAT. Later, the government promoted the private sector to engage in power generation in the forms of IPP, SPP, and VSPP. The remainder is imported from neighboring countries.

Thailand's power transmission falls under the supervision of EGAT. The power sales for the three provinces of Bangkok, Nonthaburi, and Samut Prakan are under the supervision of MEA. The remainder is under the supervision of PEA.

Later in 2007, the OERC, an independent agency, was established to supervise Thailand's energy operation for equality and fairness to consumers, producers, and all concerned who would benefit. The OERC was responsible for overall supervision of regulations relevant to power generation, power transmission, and power sales, especially monitoring energy markets, electricity prices, licenses for energy industry operation, transmission systems, distribution systems, sales, and so forth.

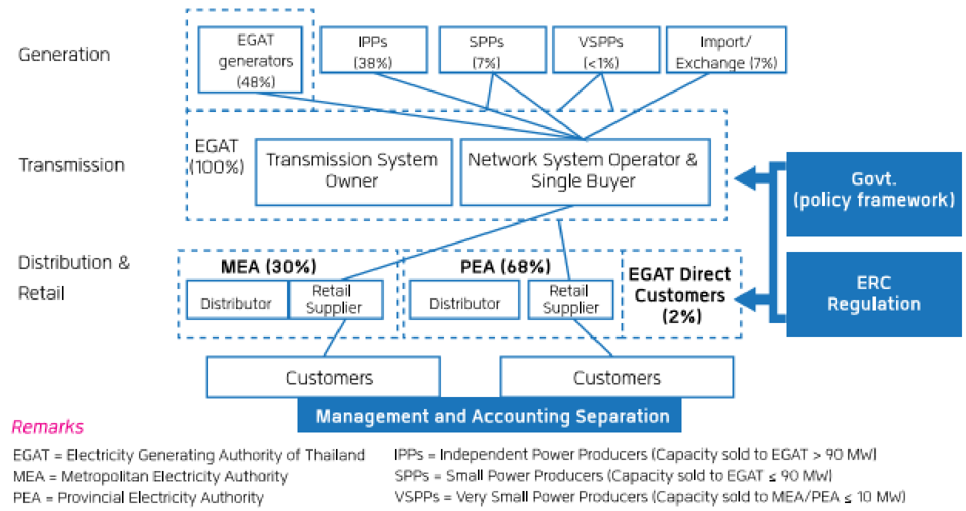

Figure 2.1 Structure of Thailand's Power Generation System

Source: Energy Policy and Planning Office (2015).

2.2.1 License Application of Solar Rooftop Project

For the submission of documents and proof of operation of solar PV rooftop, power producers from solar rooftop selling to the electricity grid with a power purchase agreement with EGAT already or to be used in building or operation not selling to the electricity grid may submit documents and proof of exempted energy industry operation at the website of the central OERC or district attached in each area where the building is located as shown in Figure 2.2.

Figure 2.2 Guideline to Receive Notification of Exempted Energy Industry Operation not Requiring License

Source: Office of Energy Regulatory Commission (2018).

Figure 2.2 shows that the operational process is as follows:

1) Entrepreneurs possessing power purchase agreement with EGAT, and with the signature of a civil engineer, submit the license request online with OERC.

2) Notify local administrative organizations (subdistrict administrative organization, municipality, district office) that there is installation of solar rooftop on residential buildings before proceeding.

3) OERC notifies of permission to proceed.

4) Receive proof of submission of the license request from the local government.

5) Entrepreneurs finish installation and notify MEA, PEA to inspect the system and make payment.

6) Register to notify of exempted energy industry operation (online or OERC).

7) Receive exemption letter from OERC and submit a copy of exemption letter to MEA, PEA.

8) After passing inspection of electricity production/connection system as stipulated by MEA, PEA, proceed with power generation from solar energy.

2.2.2 Relevant Regulations for Installation of Solar Rooftop

The regulations of OERC regarding the power purchase from solar PV rooftop, B.E. 2556 (2013) under the Article 11 (4) of Energy Industry Act B.E. 2550 (2007) which is the law with provisions pertaining to restriction on individual's rights and freedom, with Article 29 with Articles 33, 42, and 43 of the Constitution of the Kingdom of Thailand regulating what it is possible to do so under the legal provisions. OERC therefore issues regulations summarized as follows:

These regulations are used for the purchase of power from very small power producers (VSPPs) of solar rooftop power generation. MEA/PEA purchase power from VSPP of solar PV rooftop based on the criteria, methods, and conditions as determined. VSPPs wishing to produce and sell electricity to MEA/PEA must abide by the standards of safety and connection system according to the regulations of the electricity grid, as well as the regulations of the property of materials, equipment, and installation of power generation system from solar PV rooftop announced in the purchase of electricity. Also, for the security of the power system, MEA/PEA have the right to investigate or ask the VSPP to check, rectify, improve the equipment of their power distribution relevant to the power system of MEA/PEA at any time as necessary.

Processes have been established to purchase power from VSPPs through the selection according to the order of the request to sell power received with complete documents, through qualifications, criteria, methods, conditions as determined, or any other means to be announced each time. MEA/PEA responsible for the area of the determined electricity grid will announce the list of those selected who submit the request to sell power so that those who submit the request for VSPP will sign the power purchase agreement within the date as specified in the power purchase announcement.

The regulations of OERC on the power purchase from solar PV rooftop, B.E. 2556 (2013) are important for the promotion of solar rooftop power generation as they determine the role and duty of relevant agencies and entrepreneurs to avoid confusion and create order in operation leading to the accomplishment of the overall objectives.

2.2.3 Legal Request of License for Installation of Solar Rooftop

After submitting the request to sell electricity and being selected by MEA or PEA, the process will begin for the request of license according to the relevant laws as follows:

2.2.3.1 Request for license prior to installation of solar PV rooftop

1) Building modification license (Aor 1)

(1) If the building is located in a controlled area according to the Building Control Act, a building modification license is required. For the location of the building's controlled area, the question can be addressed to a local administrative organization such as municipality office/subdistrict administrative organization in the area where the building/Bangkok district office is located.

(2) If the building is located outside the area of building control, a building modification license is not required. However, if it is an especially large building (over 10,000 sq. m.), a building modification license must be sought. In addition, if the building is located outside the controlled area, the building's certified letter is requested from a local administrative organization as well.

(3) If the roof of the building is reinforced concrete, the building modification license is not required.

(4) Documents accompanying the license application in three copies namely Kor 1 with the plan showing diagram and roof structure, structure supporting solar panels, details of installation, list of calculation of structure, building survey form, certified documents by engineers who design and control civil work, and accompanying documents.

2) Energy industry operation license (Ror Ngo 4)

(1) In case of the installation of solar panels combined with invertor from 5 Horse power or 3.73 kW upward, it is considered a factory according to the Factory Act which requires the Ror Ngo 4 license from OERC.

(2) Documents accompanying license application of Ror Ngo 3 in three copies, including a plan showing diagram and roof structure, structure supporting solar panels, details of installation, list of calculation of structure, building survey form, certified documents by the engineers who design and control civil work, single line diagram, certified documents by the engineers who design and control electric work, and accompanying documents.

2.2.3.2 License after installation of solar PV rooftop

1) Controlled energy production license (Por Kor 2)

(1) If the solar PV rooftop has kWp lower than 200 kW, Kor Por 2 form is not required.

(2) If the solar PV rooftop has kWp from 200 kW upward but not exceeding 1,000 kW, Kor Por 2 form is required.

(3) Documents accompanying the application in two copies of Por Kor 2 form Include Por Kor 1 form and other accompanying documents.

2) Notification of exempted energy operation not requiring license.

(1) Solar PV rooftop with kWp of lower than 1000 kVA must submit the form of exempted energy operation not requiring license to OERC.

(2) Notification form and accompanying documents in one copy.

(3) Fill in the information at the OERC website. The applicant can apply for the license at the agencies under OERC.

The request for the license to install the solar rooftop involves the Ministerial Regulation No. 65 B.E. 2558 (2015) issued under the Building Control Act B.E. 2522 (1979). As the building must be modified to install solar panels, the request must be sought for the building construction or the building modification license (Aor 1) together with the license for energy industry operation (Ror Ngo 4) according to the Factory Act and license to produce controlled energy (Por Kor 1).

2.2.4 Grid Code

To ensure the supervision of power quality and security of power system, power producers who will sell power to the system must adhere to the Grid Code as stipulated by EGAT as follows:

For the technical aspects, technical requirements must be adhered to, namely assurance that the electric current flowing in the distribution line or the transmission line does not exceed the limit and does not affect the security of the overall power system, does not affect the pressure in the power grid to be outside the standard criteria, and does not affect the total short circuit of the power grid of over 85% of the range that can cut the short circuit of the circuit breaker or preventive equipment.

For the control of electricity quality, the control system is designed for electricity distribution in parallel with the determined electricity grid, namely, to control and ensure that pressure and power factor meet the standards that determine and control power frequency in the ranges of 50 ± 0.5 Hz, control and ensure that voltage fluctuations and harmonics meet the standard criteria, as well as control of volume of direct current to the electricity grid and install the power quality meter for power producers with the capacity of over 1 MW and power producers with the converter generator with the combined capacity of over 250 kW, installation of long-distance control system and communication system, as well as installation and setting of the control system of wattage to maintain the pressure level for power producers who distribute electricity through converters (Provincial Electricity Authority, 2016).

Solar rooftop power generation must operate according to the process of installation license to control and ensure that the installation meets the safety standards.

The roof for installation must pass the standards as certified by expert engineers to notify the energy regulatory agency so as to be fully informed of the situation of the country's energy production and to accompany the formulation of plan, policy, and energy management of the country, as well as formulation of the guideline of waste disposal from products at the end of life. The system installation requires standard equipment based on the regulations of electricity connection to ensure the country's efficient and secure power system. Technical limitations must also be managed for renewable energy and readiness must be maintained to ensure efficient power generation.

2.3 Solar Rooftop Technology

Solar energy is an alternative naturally renewed energy. It has a variable, which is solar panel, that transforms sunlight into energy. This is a semiconductor such as silicon with a pure, thin panel. When sunlight falls on the panel, photon particles will transfer energy to electrons in the semiconductor so that there is sufficient energy to escape from the gravity of the atom and move independently. When the electron moves to complete its cycle, there will be direct current. Power generation from solar energy can efficiently generate electricity during daytime on the average of 4-5 hours/day. This can solve the shortage of electric power during daytime.

2.3.1 Solar Cells Widely used at Present

Solar cells are divided into two major groups namely:

1) Solar cells made from silicon semiconductor. It is divided by the characteristics of the crystal namely crystal and amorphous. The crystal is divided into two types, namely, single crystalline silicon solar cell and poly crystalline silicon solar cell. The amorphous is morphous silicon solar cell.

2) Solar cells made from a compound that is not silicon with over 25% of high efficiency but very expensive. It is not widely used around the world and it is mostly used for satellites and light focus system. However, the development of modern production process will reduce the costs and it will be used more in the future (Department of Alternative Energy Development and Efficiency, 2018)

2.3.2 Composition of Solar Cells

Electromotive force made of only one solar cell is very low. For usage, many cells must be linked in a series to increase electromotive force. The cells that are linked with one another at the appropriate number and size are called a solar module or solar panel.

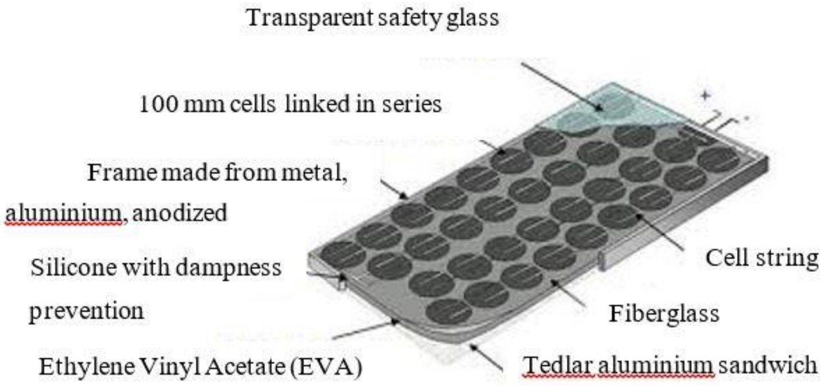

Figure 2.3 Composition of Solar Cells
Source: Department of Alternative Energy Development and Efficiency (2018).

Solar cells are designed for convenient usage. The front of the solar cells consists of glass plate with a low composition of iron. It has the property of good transparency and serves as a shield to protect the cells. The cells must have the property of a high standard of dampness prevention as they are exposed to sunshine and rain for an extensive period. The assembly requires materials that are durable and have a high standard of dampness prevention such as silicone and Ethylene Vinyl Acetate (EVA), and so forth to protect the upper glass plate of the solar cells. The frame of the materials is strong but sometimes not necessary if the glass plate is sufficiently reinforced which can replace framing as well. Thus, solar cells are laminate and convenient for installation.

2.3.3 Power Generation from Solar Cells

Power generation from solar cells is divided into three systems, namely:

1) PV Stand Alone System

This is the power generation system designed for use in rural areas without a transmission system. The important system equipment consists of solar cells, equipment to control battery charge, battery, and equipment to independently change direct current into alternating current.

2) PV Grid Connected System

This is the system designed for power generation through equipment that changes direct current into alternating current, directly to power transmission system. It is used to produce electricity in urban areas or areas with access to a distribution system. The main system equipment consists of solar cells and equipment to change direct current into alternating current connected to a distribution system.

3) PV Hybrid System

This system is designed to work with other electricity-producing equipment such as solar cells with wind energy and diesel engine, solar cells with wind energy and hydro power, and so on. This system depends on the design according to the specific objectives of the project (Narongrit Sanajit, 2018)

2.3.4 Potential of Thailand's Solar Energy

In general, the potential of solar energy in an area is high or low depending on the solar radiation that falls on the area. The area receiving a great deal of solar radiation will have high potential for solar energy use. According to the information of solar energy potential by the Department of Alternative Energy Development and Efficiency, Thailand has very high potential for solar energy which is suitable for power generation from solar cells. Figure 2.4 shows that Thailand will receive solar radiation the highest in April. The area that receives solar radiation the highest (19-20 MJ/m2-day) is in the northeast and the central plains or 11% of the country's total area. The daily intensity of solar radiation on the yearly average of the country's total area of 18.0 MJ/m2-day which is high intensity compared with other countries (Department of Alternative Energy Development and Efficiency, 2017a).

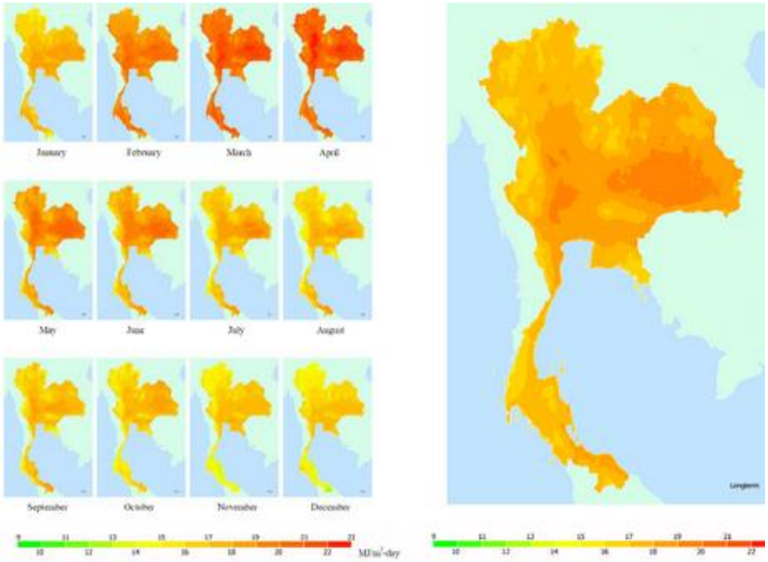

Figure 2.4 Map of the Potential of Solar Energy in Various Months and Map of the Potential of Solar Energy on Average and all Year Round in Thailand

Source: Department of Alternative Energy Development and Efficiency (2017a)

The public sector operates the project to install solar rooftop to promote the use of renewable energy and respond to the current demand for energy. Solar cell is technology that assists people to generate electricity for their own use. The excess of electricity will be sold to the public sector. Solar cell is not a complicated technology. People can learn and understand it quite easily.

The efficient installation of solar rooftop requires installation in the areas with high intensity of sunlight to be able to produce a large amount of electricity, as well as the installation of solar cells in the degree that can receive a large amount of solar radiation. Generally, the installation of solar cells in Thailand prefers turning the front of the solar cells toward the south with an inclination of approximately 10 -18 degrees with the earth (depending on geographical features).

However, solar rooftop power generation still faces instability and inconsistency depending on reception or non-reception of sunlight. The stability of solar rooftop power generation for electricity consumers abroad will pose a problem once the share of solar power generation is over 30% of the country’s power production capacity (if exceeding this, there must be management of the efficient flow of electricity in parallel with the use of smart grid system for control). At present, the share in

Thailand is still very low or less than 1% of the centralized power generation system with the ability to still tolerate the fluctuation of renewable sources of power generation (Chumnong Sorapipat, 2017).

2.3.5 Solar Rooftop in other Countries

More countries are promoting solar energy and the trend to install solar power generation is increasing. The top ten countries with the most installed solar power capacity in the world is shown in Table 2.3

Table 2.3 Countries with the most Installed Solar Power Capacity in the World

Rank	Year	Country/Area	Installed Capacity (MW)
1	2019	China	205,072.165
2	2019	Japan	61,840.000
3	2019	United States of America	60,539.900
4	2019	Germany	48,960.000
5	2019	India	34,831.384
6	2019	Italy	20,900.000
7	2019	Australia	15,928.000
8	2019	United Kingdom	13,398.300
9	2019	France	10,562.025
10	2019	Republic of Korea	10,505.102

Source: International Renewable Energy Agency (2020).

However, solar power generation in large quantities may affect the overall electricity system. For example, in Australia, there is a large quantity of solar rooftop installation which causes electricity fluctuations in the transmission system. Australia’s main power producer equivalent to Thailand’s EGAT (Pulling the plug: The market regulator wants to control how much solar power households send to the grid, ABC News: James Carmody, 2019) is requesting the authority to cut the power supply from solar rooftop into the system in case of high fluctuations in the transmission system.

2.3.6 Technical limitations of Solar Rooftop Power Generation

Solar power generation has technical limitations in transmission and distribution systems as follows. The installation of the solar power generation system in the same area and in large quantity risks affecting the quality of electricity especially the voltage in the area where there is no solar power generation. This may impact security if there is a large change in the volume of power generation. The positive and negative impacts can be divided as follows:

The positive impact of solar rooftop on power generation system is the leverized cost of electricity (LCOE) of the solar rooftop system which at present is lower than the average retail prices. Self-consumption will help save costs. If the government will buy the electricity, the overall costs of power generation in the country will reduce. Solar rooftop power generation system will also reduce the demand of the country's peak load during daytime (2.00-3.00 pm) and offset the investment in construction of power plant of the system.

The positive impact of solar rooftop on the power distribution system is to reduce the demand and electric power flowing in the feeder by upgrading the voltage and reduce the voltage drop at the end of the feeder, as well as reduce power loss in the feeder.

The negative impact on the power generation system is more fluctuations when there is a large amount of renewable energy in the system and compensation of the large amount of fluctuation. The number of power plants with quick response may not be sufficient. The operation of power plants with a swifter response will increase the overall system costs. The rapidly increased loading will reduce the ability to operate base power plant. Moreover, peak time is changed from 2.00 pm to 6.00-8.00 pm. However, the loss of power generation from renewable energy at 2.00 pm may increase the demand for power in the system to be higher than peak time in the short run (Energy Research Institute 2017).

Therefore, the technical impact of the solar rooftop on the power system can be concluded as follows. If the solar rooftop installation is not too great, it will positively impact the production system (transmission system) and distribution system. For example, solar rooftop power generation is balanced with the demand of electric consumption in the area, encouraging mainly self-consumption. However, if the solar rooftop installation is too great, it will have a technical impact on the production system (transmission system) and distribution system. Most problems can be solved by engineering technics and may have higher costs for improvement of the power system.

2.3.7 Power Bank System

Due to the problems of uncertainty or instability in the amount of electricity produced from solar renewable energy, the guideline to address the problem is to use the power bank system as a reserve of the produced electricity during the time solar cells cannot produce electricity. At present, the technology for power bank system offers many types such as pumped hydro energy storage, compressed air energy storage, lead acid battery, lithium ion battery, and vanadium redox flow battery. The selection of power bank system requires the consideration of many factors such as highest volume of required power production capacity, required power capacity, duration and frequency of power supply, and limitations of the area for installation to ensure that the power bank system is suitable to the required work.

Most batteries are suitable for energy reserve of not exceeding 100 megawatts. The accumulation of energy requires electric and chemical reactions with different properties based on the types of chemicals used to make electrodes. Many types of battery still have high costs. However, the lithium ion battery is gaining in popularity due to its light weight and compact size compared to other types of battery. Its costs tend to decrease and it has a longer service life (Hadjipaschalis, Poullikkas, & Efthimiou, 2009).

It can be said that the power bank system can adapt the energy fluctuation coming from small and large electricity sources and enhance reliability and flexibility of the system in small and large sub-stations as well.

2.3.8 Disposal of Solar Cells

Solar cell waste is the residue of solar power generation. Similar to other electronic waste, it creates environmental and health problems. Disposal by incineration will lose energy and increase cost and will also generate carbon dioxide and dioxin from incorrect burning. Disposal by landfill will spread heavy metals, including lead and cadmium, into soil and natural water sources and probably result in loss of food and water sources in the future. It is estimated that the amount of solar cell waste accumulated between 2002-2016 was 388,347 tons or 12.9 million cells. The amount of accumulated waste in 2020 was 551,684 tons or 18.38 million cells requiring disposal (Nitcha Buranasing, 2018).

In Europe and Japan focus on the disposal of the waste with clear supervisory laws. Quality is added and rare metals are extracted from these wastes and fed into industry again to enable raw materials to have stable prices, in sufficient amount, and able to solve the problems of metal contaminations into the environment.

Due to these problems, the Department of Industrial Works (DIW) devised the Master Plan to Dispose Electronic Product Waste: Solar Cells to determine the guideline for disposal of expired solar cells. The current method is landfill as there is no other method of disposal. Although recycling is a superior method, it may not be worth the investment. There must be specific technology to separate this type of waste so there is investment at the macro level.

As for waste from solar power generation, apart from solar cells, reserve battery with increased production and consumption may result in problems of disposal as well. At present, the Pollution Control Department devised the 20-year Pollution Management Strategy and the Pollution Management Plan 2017-2021. Measures or system have been formulated to accommodate the disposal of battery waste from the promotion of the use of electric vehicles, hybrid cars, and products made from renewable energy such as solar cells.

The regulations of the OERC on measures to prevent, rectify, monitor, and inspect the impact on the environment from solar power producers of photovoltaic technology requiring energy industry operation license 2014 item 4 specify that "…solar power producers from photovoltaic technology installed on rooftop requiring energy industry operation license must follow measures to prevent, rectify, monitor, and inspect impact on environment based on the Code of Practice (CoP) attached at the end of the regulation especially under the topics 1) Measure on design of installation of solar energy system 2) Measure on waste and solid waste management."

Measures on design of installation and waste and solid waste management for solar power producers of photovoltaic technology exempted from energy industry operation license 2014 item 4 specify that "...solar power producers must abide by the Code of Practice (CoP) attached at the end of the regulation. Solar power producers must submit the documents and proofs showing the design of system and equipment of the project in line with the standards and regulations ...". Only two measures will be stressed. The measure regarding the design of power system from solar energy and the measure regarding waste and solid waste management. The objectives are to manage waste and solid waste from activities of project construction and to prevent contamination from solid waste in the adjacent environment (Department of Alternative Energy Development and Efficiency, 2017b).

Regarding management in other countries, measures and laws are devised as follows:

1) Germany

(1) Law imposed on management of electrical and electronic equipment similar to EU's WEEE Directive called ElektroG.

(2) The public sector provides the Office of Registrar to register those who generate e-waste, including importers and sellers as responsible entities. The producer is responsible for recalling, compiling, and taking expired electrical and electronic home appliances to disassemble, recycle, or forward to a factory that can perform the duty.

(3) The private sector or producers have an important role in collecting, disassembling, recycling, and disposing of waste which will impact the design of various tools as ElektroG specifies that the tools must be able to be 80% recycled by weight.

(4) The producers gathered to establish an organization called PV Cycle, responsible for collecting, disassembling, recycling, and disposing of the expired panels in 2007.

2) EU

(1) WEEE directive (Directive 2002/96/EC) is the law enacted by EU to manage electrical and electronic waste among EU members.

(2) The recast WEEE directive (Directive 2012/19/EU) gives panel producers the direct responsibilities by setting the recall system and recycling, as well as management, reporting, and finance relevant in each member country. The producer under this law means factories, distributors, importers, and sellers in an online system.

(3) RoHS recast directive 2011/65/EC effective on 3 January 2013 with the objectives of reducing and canceling the use of hazardous chemicals in power generation from solar energy.

3) Japan

(1) The use of two laws not specific to PV, namely, Law for Promotion of Effective Utilization of Resources (LPUR), and Law for Recycling of Specified Home Appliance (LRHA).

(2) Waste owner pays waste management fees to the distributor at the collection point. In case the distributor cannot manage, the Association of Electric Home Appliance (AEHA) will step in to collect waste instead.

(3) Distributors will coordinate to collect waste for recycling according to the country's policy (The Thailand Research Fund, 2018).

The technology of power generation from solar energy is not complicated. People can learn about it and understand it easily. As Thailand is geographically situated in the area that can receive plentiful sunlight, its ability to generate power is efficient. However, transmission systems and energy management systems must be developed and improved for efficiency. For example, innovation to supervise and provide services for electricity operations, including the study of new forms of market structure, study of new forms of service fees, electricity management systems, energy storage systems, and disposal of solar cell waste must be set to accommodate the management of the energy sector in line with technological advancement.

2.4 Project Evaluation Based on CIPP-I Model

This study applied the CIPP Model to the evaluate the effectiveness of solar rooftop power generation because it was the generally and currently recognized model. It was referred to in many evaluations and it could explain the quality of the program that covered all relevant issues. Apart from the evaluation of context, input, process, and output, the researcher added the evaluation of impact to measure the results of the project's operation holistically in terms of both positive and negative impacts in order to make decisions, improve, or develop, and enhance for maximum benefit.

Project evaluation meant a process that seeks to determine whether policy/plan/project reached the objectives and goals as specified or not, with the standards and measuring tools that were accurate and reliable. The objectives of the project evaluation were as follows:

1) To support or cancel the project. Evaluation was a tool that helped decide whether a project should be cancelled or supported for further enhancement. Especially, new projects were not arranged in the form of experimental projects so they might make mistakes or fail easily. However, the project's failure might not always be the executive's failure. Therefore, if that the project was evaluated to meet the objectives and goals, it should continue to operate. On the other hand, if after evaluation the project had problems or more negative impact, it should be canceled.

2) To determine if the progress of the project's operation met with the objectives and goals, or criteria, or standards as specified.

3) To improve work. If some of the implemented projects did not totally fail but did not accomplish all objectives, they should be improved. The defects of the project such as lack of people's cooperation, non-compliance with people's value, lack of public relations, or responsible organization's low competency could be considered. When the results of the evaluation are known, the project could be improved or rectified on specific points.

4) Study Alternative: Usually, for the implementation of a project, the project operator would seek at least the two best possible options. Therefore, the evaluation was to compare the alternatives before deciding which alternative to reduce risk.

5) To extend the implementation of the project. If the results were not continuously monitored and evaluated, the project's success might not be able to be determined. However, with regular evaluation of project results, the project would reach the determined objectives. Thus, the project results could be extended. However, this result does not mean that extension was possible in all areas. The extension must take into consideration the dimensions of population, time, place, and various situations. For instance, the project to cultivate cold climate plants would succeed in the north. The enhancement to other regions might not always succeed. Consideration must be taken in terms of geography, climate, ethnic groups, norm, and so forth. Therefore, the fact that a plant that could grow in one area might not grow in another area or what was successful during one period may not be so in another period should be taken into consideration (Sompit Suksaen, 2002).

Daniel L. Stufflebeam (1971) devised the issues of evaluation based on the four types of CIPP Model according to the first English letters of the model as follows:

1) Context Evaluation (C) was the evaluation to consider the rationale to operate project, problems, and appropriateness of the project's goals.

2) Input Evaluation (I) was the evaluation to consider the feasibility of the project, appropriateness, and sufficiency of resources used in operating the project.

3) Process Evaluation (P) was the evaluation to find defects of the project's operation to be used as information to develop, rectify, improve the next phase of the operation for more efficiency, and investigate activities, time, resources used in the project, as well as leadership, and people's participation. Process evaluation would be very useful to find strengths and weaknesses of policy/plan/project.

4) Product Evaluation (P) was the evaluation to compare the output with the project's objectives or standards as determined, as well as consider the issues of merging, cancelling, extending, or changing the project.

However, as a project was a type of system, it could apply system analysis to be used in the project analysis by adding the impact evaluation. This evaluated the project's operation impact on the target group (the group directly affected by the project's operation) and non-target group (the group indirectly affected by the project's operation) by considering both positive and negative impacts in order to determine the guideline to improve or rectify the project and to encourage recognition of the project, resulting in the project's success (Chamlong Poboon, 2011).

In this study, the project evaluation based on the CIPP-I Model was used as a framework to study the factors that promote solar rooftop power generation because it covered all issues of promotional factors that enabled policy or promotion to succeed. Apart from the factors of context, input, process, and output, the researcher added the impact factor to be able to determine the factors for the maximum benefit of development and enhancement.

2.5 Theories of SWOT Analysis and TOWS Matrix

SWOT was the tool to analyze situations, and to assist executives to determine strengths and weaknesses of internal factors, and opportunities and threats from external factors that impacted the promotion of solar rooftop power generation in order to appropriately formulate an operational strategy.

Internal factors consisted of S: Strength which was the strength or advantage from internal factors, and characteristics or unique features of solar rooftop power generation facilitating success, and W: Weakness which was weakness, disadvantage, or drawback from internal factors promoting solar rooftop power generation negatively, impacting the promotion which needed to find the solution to the problem.

External factors consisted of O: Opportunity which was the opportunity of possibility to promote solar rooftop power generation. An organization's external environment facilitated promotion. Opportunity was different from Strength as it was from external factors but impacted positively on the promotion of solar rooftop power generation, and T: Threats which was the risk, threat, limitation, or obstacle of promotion. This was a factor in the external environment that negatively impacted promotion which could not be changed or rectified.

SWOT Analysis enabled understanding of the promotion of solar rooftop power generation in terms of strengths, weaknesses, opportunities, and threats. It enabled understanding of the changes from internal and external factors. It also determined the framework to plan in line with the potential of technology in solar power generation.

However, it was insufficient to formulate the strategy. SWOT must be additionally analyzed using TOWS Matrix in order to formulate a more detailed strategy.

TOWS Matrix analyzed the strategy of four forms in pairs, namely: SO Strategy paired positive internal environment of Strength and positive external environment of Opportunity. This was the use of strength plus good opportunity to formulate proactive strategy for the organization. WO Strategy paired negative internal environment of Weakness and positive external environment of Opportunity and it was the use of good opportunity to close the gap of an organization's weakness or reduce the weakness. Additionally, ST Strategy paired positive internal environment of Strength and negative external environment of Threat and it was the use of an organization's strength to prevent threat which was the use of strength to avoid threat. Lastly, WT Strategy paired negative internal environment of Weakness and negative external environment of Threat to reduce weakness and avoid threat with the main goal of preventing or avoiding an organization's deteriorating situation.

The researcher used SWOT Analysis and TOWS Matrix to present an operational strategy that can motivate more solar rooftop power generation, leading to integrated energy management of all relevant agencies and across all concerned sectors.

2.6 Patterns to Promote Solar Rooftop Power Generation

Yaowadee Wiboonsri (2008) gave the definition of pattern as the method that any person transfers thoughts, understanding, as well as imagination of any phenomenon or story using various types of communication such as painting, portrait, continuous diagram, or mathematical formula that can be readily understood. At the same time, the presenter could present stories or issues concisely under systematic principles. Brown and Moberg (1980) provided the concept of the composition of the pattern through the synthesis of the pattern from the System Approach and the Contingency Approach. They discussed the compositions of the pattern as follows: (1) Environment, (2) Technology, (3) Structure, (4) Management Process, and (5) Decision Making. The determination of the compositions of the pattern including the number, structure, and relationship would depend on the phenomena, factors, or variables under study.

For the preparation of the pattern to promote solar rooftop power generation in this study, a review was conducted of past policy and promotion of solar rooftop power generation, and a compilation of data from relevant persons using the Delphi technique was conducted. Analysis and synthesis were also conducted on the strengths, weaknesses, opportunities, and threats in the support (SWOT Analysis and TOWS Matrix) to develop a strategy to be used as a guideline to promote solar rooftop power generation so that it can reach the objectives or the goals of the promotion.

2.7 Previous Research

Renewable energy is a choice for the development of future energy. It is a natural inexhaustible energy source. It can respond to energy demand and reduce the use of fossil-based fuel polluting the environment. At present, the world is facing climate change. Therefore, many countries formulate policies to develop alternative energy. For example, Islam and Meade (2013) studied the installation of solar rooftop for power generation in households. They argued that at present the public sector supported the feed-in tariff project, resulting in more installation of solar rooftop projects. It was found that the installation of solar rooftop in households could save costs for non-renewable energy. This was in accordance with Kaufmann and Vaid (2016) who studied renewable energy and sustainability and found that tax incentives and subsidies to support the project could drive the expansion of the project to more areas as the installation of solar rooftop had high costs.

Kar et al. (2016) studied the development of the solar energy market in India and found limitations for the installation of solar rooftop in terms of budget. High investment was needed for the system installation and maintenance costs were high, with some areas unable to afford to buy solar cells due to high costs. Therefore, the development of a market system of solar energy was important. This was in accordance with Gautam et al. (2015) who assessed the potential of solar rooftop to solve energy shortages in Nepal and found that entrepreneurs must consider costs in maintaining the system and investment in installation due to high costs. Moreover, Flowers et al. (2016) studied the impact of climate on the costs of solar energy generation and revealed that PV was widely used but worthiness must be considered in the installation of solar cells (costs in system/installation of the system/received benefit) due to differences in the climate of each area. Design or system structure and environment therefore required awareness to develop solar rooftop installation project. For example, Broderick et al. (2015) studied energy design and stated that the reliance on energy generation of solar cells required a survey of design in the system installation and surrounding environment before operation. This would result in a forecast of energy consumption and system assessment leading to an appropriate system design that could contribute to maximum efficiency in power generation under the differences in geography and climate.

Salamanca, Georgescu, Mahalov, Moustaoui, and Martilli (2016) investigated the impact of climate on the use of solar energy and found that electric output depended on the solar intensity in each area. The study of the specification of the potential area and financial trend of solar rooftop by Ninsawat and Hossain (2016) revealed that installation should consider the appropriate roof to be used and required a suitable roof structure. If not, the structure must be modified for appropriateness.

Singh and Banerjee (2016) studied the impact of solar rooftop and found that installation was important as it would affect the volume of electric output and installation worthiness. In addition, Dimond and Webb (2017) studied the environmental factors and relevant installation and operational contexts and stated that they contributed to moving toward the goals of sustainable development. Therefore, the world has taken interest and operated an increasing number of such projects. Accordingly, the development of solar energy requires the taking into account of the environment for the installation and potential of investment to create sustainable energy source in the future.

Therefore, it was important that the development of solar rooftop went in parallel with balance and worthiness of other aspects. Such a study by Kannan and Vakeesan (2016) dealt with the research and compilation of data on solar energy for the world and suggested that the solar energy industry would be the best choice to meet the demand for energy in the future as it was an efficient energy source that could reduce costs and was accessible compared with other sources of alternative energy. Moreover, Islam and Meade (2013) investigated the installation of solar rooftop in households and stated that the current social conditions and people's attitude increasingly recognized new technologies. The solar rooftop technology was not complicated and the general population could learn and understand it.

Moreover, Böhringer and Rutherford (2013) dealt with the changes to Poland's low carbon economy and found that the current global trend was moving toward a low carbon society. Lahnaoui, Stenzel, and Linssen (2018) studied the technological analysis for economic system and found that at present there was demand to develop smart home system to create efficient energy management. Deng and Newton (2017) also studied the results of the policy of power generation from solar energy. They stated that the installation of solar rooftop could reduce the level of carbon dioxide in the environment.

This was in accordance with Perea-Moreno, García-Cruz, Novas, and Manzano-Agugliaro (2017) who analyzed solar rooftop output for energy sustainability as a way to reduce greenhouse gas (GHG) emissions and stated that the agreement reached on GHG emission and the renewable energy (solar rooftop) was important in the reduction of GHG emissions. This was in line with Griffiths and Mills (2016) who studied the potential of solar rooftop in UAE. It was found that solar rooftop could help reduce climate change, create good quality of life and air quality, and generate energy security.

However, Aksornchan Chaianong, Athikom Bangviwat, and Christoph Menke (2017) studied the economic impact of solar rooftop installation and found that the operation of the project to install solar rooftop had limitations in terms of costs to upgrade transmission system and the loss of energy in the transmission system. The public sector or the project operator should be aware of this issue and should study the potential of the area and other factors related to installation. Rodrigues et al. (2016) studied the economic feasibility to install small size solar cells in numerous countries and stated that the installation must consider costs and benefit as well as degradability and disposal when the panels expired.

Regarding the study of the success of the implementation of past governmental energy policy, the study reviewed the efficiency of operational processes to accomplish the objectives of projects or other policies. Goel (2016) investigated the growth of the world's solar energy and India's policy to promote solar energy by reviewing past operations. It was found that policy formulation to promote power generation from solar energy was important. Moreover, Marquardt (2015) studied the policy to promote energy in the Philippines using semi-structured interviews with experts to determine the effectiveness of the support of the country's energy and found that the policy was effective.

Aksornchan Chaianong et al. (2019) forecast the future consumption of solar energy by studying the policy to promote and prepare the grid and revealed that the relevant factors for the uptake of solar energy were payback period of system installation, readiness of electricity grid, interesting purchase prices, and reduction of system installation costs. As a result of improvements in these areas there was increased power generation from solar energy. In addition, Nualprakai Lertkirawong (2019) studied a pilot project for solar energy power generation independently installed on rooftop of producers and household consumers. It was revealed that the government sector should support incentive measures to encourage people to produce electricity themselves via the Net-Metering system or excess power purchase system of power generation from solar energy (Net-Billing). The economic analysis of power generation for own use of pilot project participants revealed the excess electricity from solar energy was at the average of 120.3-231.1 kWh/month.

Pichitkunchorn and Chayakulkeeree (2018) studied the design and economic valuation analysis of installation of solar rooftop of the building of Post Engineer Department Headquarters using a computer program to process the data of electricity generation. It was found that electric power obtained from the installation was approximately 5% more efficient in the direction of the southeast than the northwest. Electric power produced equaled 34,809 units a month or a saving of approximately 1,670,832 baht per year. The system would have a payback period of approximately 7 years and could reduce electric power usage 18% in comparison to past usage, and reduce GHG emissions by 225.56 tons of carbon dioxide annually.

Therefore, the study of the factors that promote solar rooftop power generation consider the relevant context, input, process, output/outcome, and impact. For example, context included power demand in urban areas, electricity charges, opposition to construction of a new power plant, and solar energy equipment costs. Input included social innovation/awareness/understanding, participation of households, provision of solar energy equipment, and standards certification of equipment. Process included AEDP/policy/law/regulations/incentives, electricity stability control system/energy storage system, facilitations for smart grid of MEA and PEA, current ripple/fluctuation, and electricity self-rectification. Output/outcome included expansion of power generation from solar energy, increased share of renewable energy, increased efficiency of power generation, and reduction of energy loss in the system. Impact included ability to reduce demand of new power plant/energy security/diversity, increase employment, increased use of domestic (solar) resources, creation of a good image/clean environment/appreciation from people/acceptance, and economic growth to seek the probability or trend of project development. Policy was crucial to drive the creation of projects in terms of incentives and readiness of transmission system. Any limitations the in transmission system would not enable the project to operate in any particular area. Power generation from solar energy must be appropriately installed to enable efficient power generation as solar energy has little impact on the environment.

The Delphi technique was also used to study the views of Thailand’s experts to acquire viewpoints and data to develop the promotion of power generation from solar energy in the future under the framework of CIPPI Model. Moreover, the study was conducted on the expansion of solar energy outside the system. SWOT Analysis and TOWS Matrix were also conducted to present the pattern showing the method to drive the promotion of solar rooftop power generation in the future.

CHAPTER 3

METHODOLOGY

3.1 Conceptual Framework

This research used the Delphi technique to reveal experts' views to be used to serve as the basis for the development of a model for the future promotion of solar rooftop power generation. The Delphi technique was used focusing on collection, consideration, decision-making, and unity in the probability of the future (Jensen et al., 1996). The issues were then summarized using the CIPPI Model framework as it covered all promotional issues/factors that enabled policy or promotion of power generation from solar energy to succeed. Apart from the factors of Context, Input, Process, and Product, the researcher also added the factor of Impact to determine the factors of the development/enhancement for maximizing benefit. Data analysis was also conducted on the expansion of solar power from the import of solar panels (trade database of Ministry of Commerce and Customs Department, 2002-2019) to apprehend the present situation of power generation from solar energy in Thailand. SWOT Analysis was conducted, as well as the analysis of the strategy to promote solar rooftop power generation with TOWS Matrix to present the model to promote sustainable solar rooftop power generation.

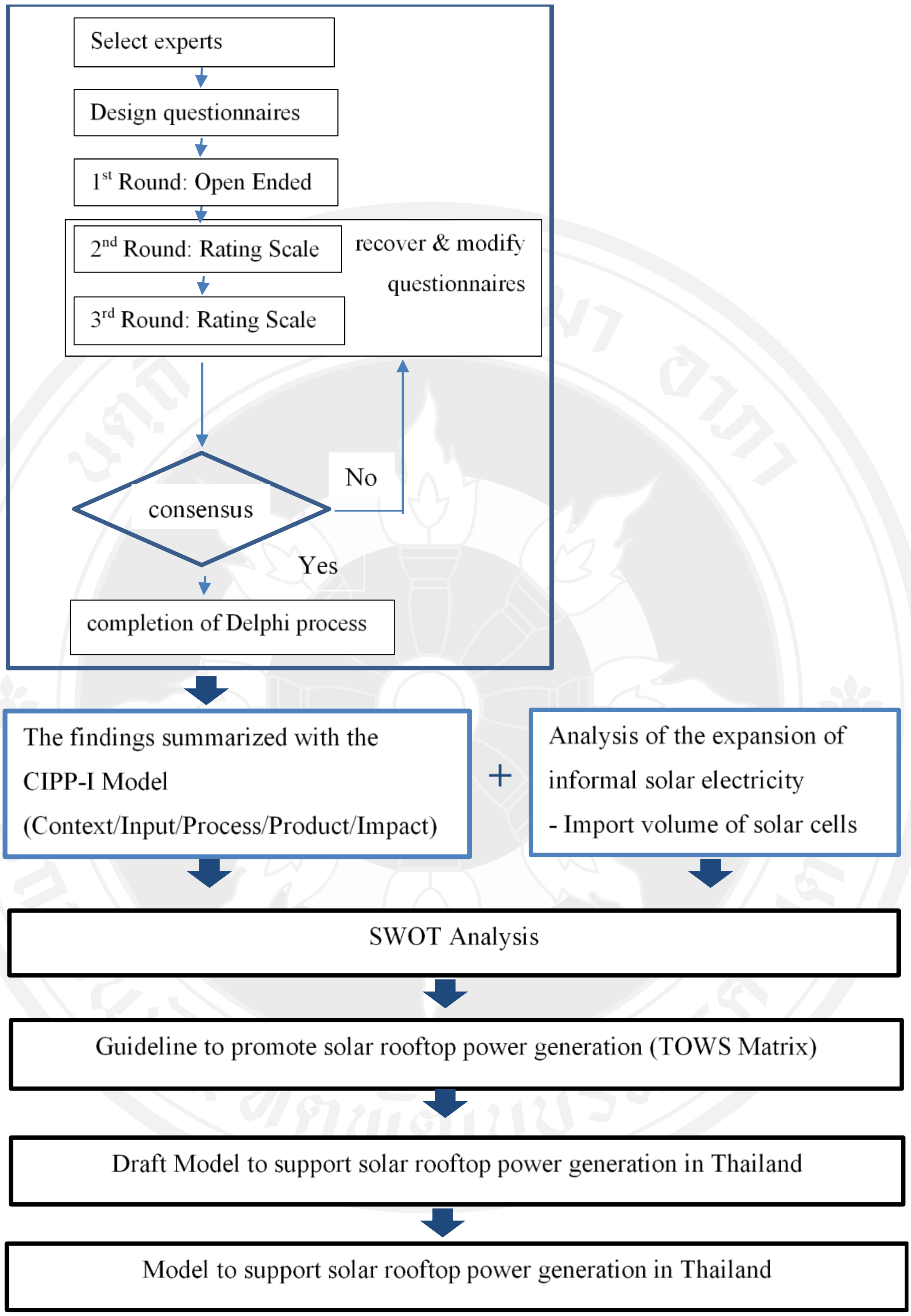

Figure 3.1 Research Conceptual Framework

Figure 3.1 illustrates how the researcher studied the factors to promote solar rooftop power generation by using the Delphi technique. The study was based on the collection of views of 19 experts in three rounds to obtain answers or factors of promotion that were consistent and in the same direction. The findings of the issues were then summarized with the CIPP-I Model framework in parallel with the analysis of import of solar panels (trade database of Ministry of Commerce and Customs Department, 2002-2019) to apprehend the expansion of the country's solar power, production capacity of solar energy in the system as registered with the responsible government agencies and informal solar energy capacity to apprehend the present growth of power generation from solar energy in Thailand. The data from the two parts were then used for SWOT Analysis and TOWS Matrix to formulate the guidelines to promote solar rooftop power generation and then to formulate the (draft) model. The draft model was evaluated in terms of its implementation by those involved, and then the revised model was addressed accordingly.

Table 3.1 Factors to Promote Solar Rooftop Power Generation Based on the Framework of the CIPP-I Model

	Criteria	**Reference**
Context	Demand for electricity in urban areas/urban growth/population in urban areas	Griffiths and Mills (2016); Perea-Moreno et al. (2017)
	Electricity prices/oil prices	Islam and Meade (2013)
	Opposition to construct new power plant	Kaufmann and Vaid (2016)
	Equipment for solar energy is cheaper/technological advancement	Islam and Meade (2013)
	Reception of sunlight	Zahedi (2009); Tooke, Coops, Voogt, and Meitner (2011); Ninsawat and Hossain (2016); Salamanca et al. (2016); Singh and Banerjee (2016)

	Criteria	Reference
	AEDP/policy/law/regulations/ incentives	Dinçer (2011); Schwartz (2010); Aksornchan Chaianong et al. (2017); Sommerfeld, Buys, and Vine (2017)
Input	Social innovation/awareness/understanding	Islam and Meade (2013); Griffiths and Mills (2016); Perea-Moreno et al. (2017)
	Participation from households	Griffiths and Mills (2016)
	Supply of solar energy equipment/ quality assurance of equipment	Gautam et al. (2015); Rodrigues et al. (2016)
	Standard certification of equipment/ training for skill in installation	Gautam et al. (2015)
Process	System to control electricity stability/energy storage system	Aksornchan Chaianong et al. (2017)
	Accommodations of Smart Grid of MEA and PEA	Cardenas, Zapata, Franco, and Dyner (2017)
	Current ripple/fluctuation (power surge/brownout)/data compilation/data processing/system of self-rectification	Kurdgelashvili, Li, Shih, and Attia (2016)
Products	Expansion of power generation from solar energy	Griffiths and Mills (2016)
	Increase share of renewable energy	Lahnaoui et al. (2018)
	Increase efficiency in power generation	Yadav and Bajpai (2018)
	Reduce energy loss in the system	Jo, Carlson, Golden, and Bryan (2010)
Impacts	Economic growth	Bayo (2016); Mitscher and Rüther (2012); Statler, Adams, and Eckmann (2017);
	Ability to reduce demand of new power plant	Kaufmann and Vaid (2016); Aksornchan Chaianong et al. (2017)

Criteria	Reference
Increase in employment	Bayo (2016)
Energy security/diversity	Breyer, Koskinen, and Blechinger (2015); Cardenas et al. (2017); Deng and Newton (2017)
Creation of good image /clean environment / people's appreciation/ recognition	Louzazni, Aroudam, and Yatimi (2014)
Increase use of domestic resources (solar energy)	Böhringer and Rutherford (2013); Griffiths and Mills (2016); Cardenas et al. (2017)

Table 3.1 was derived from the literature review so as to propose the factors to promote solar rooftop power generation and show the consistency of factors found in other studies.

3.2 Methodology

3.2.1 Determine the research questions related to the factors to promote solar rooftop power generation according to the CIPP-I Model framework.

3.2.2 Select experts in relevant agencies. There were 19 experts selected for this research utilizing the Delphi technique with small error rate as shown in the Table 3.2 (Macmillan, 1971, May 3-5).

Table 3.2 Number of Experts Selected for the Research with the Delphi Technique

Panel size	**Error reduction**	**Net change**
1 - 5	1.02 – 0.70	0.50
5 - 9	0.70 – 0.58	0.12
9 - 13	0.58 – 0.54	0.04
13 -17	0.54 – 0.50	0.04
17 - 21	0.50 – 0.48	0.02
21 - 25	0.48 – 0.46	0.02
25 - 28	0.46 – 0.44	0.02

Source: Macmillan (1971, May 3-5).

3.2.3 Construct the tool used in the research for data collection which was questionnaire. The data collection was divided into three rounds depending on the findings of each round. Each round consisted of the following:

Round One: Open-ended questionnaire with wide-ranging questions, covering research issues to collect views of each expert, then analyze and synthesize the views into issues to determine the framework of the problems in the following round.

Round Two: Developed from the answers to the questionnaire in Round One by collecting views of all experts, deleting the repeated information. Then, the Rating Scale questionnaire was constructed and returned to the same experts to seek their views with ranking of the importance of each question, as well as reasons for or against in the space at the end of the questions. The data analysis of the questionnaire in this Round would seek the median, mode, or interquartile range (Suvimol Vongvanich, 2005).

Round Three: Rating scale questionnaire was developed based on the answers from the questionnaire in Round Two by considering the interquartile range (IR). If the IR was low, it meant that the experts' views were consistent with one another and could be summarized. If the IR was high, it meant that the views were scattered and could not be summarized. The new questionnaire must be constructed in Round Three with the same questions as in Round Two with additional positions of median, IR, and signs written showing the positions as answered by the experts in the questionnaire in Round

Two, and then returned to the same experts to confirm the same answers or change the new answers (Suvimol Vongvanich, 2005).

3.2.4 Data analysis was summarized after the answers of the experts were consistent and in the same direction by mainly considering the interquartile range to summarize the results of the data analysis according to the CIPP-I Model framework to apprehend the factors to promote solar rooftop power generation in the Context, Input, Process, Product (Output and Outcome), and Impact resulting in increased solar energy generation.

3.2.5 Analysis of the expansion of informal or unregistered solar electricity using the import of solar panels into Thailand data (trade database of Ministry of Commerce and Customs Department 2002-2019) to apprehend the present production capacity of the installation of solar energy in Thailand (formal with registration at responsible government agencies and informal).

3.2.6 The analysis was conducted of the factors motivating solar rooftop power generation for a concrete promotion process. Consideration was also given to the reasons for the expansion of unregistered generation to improve the guideline for promotion or the guideline for increasing registrations with the public agencies to ensure efficient energy management from the beginning of the process until the end of life.

3.2.7 SWOT Analysis and analysis of TOWS Matrix was conducted by analyzing the internal factors under the 4M management principles (Man, Money, Material, and Management). Then, analysis was conducted on external factors using the PESTLE analysis (Politic, Economic, Social, Technology, Legal, and Environment) to present the model.

3.2.8 Use the strategy obtained from the analysis of TOWS Matrix for the synthesis of the model using the System Approach with the management principles of energy situation in Thailand in devising the composition of the model to construct the (draft) model, evaluation of the probability of the use of the draft by those concerned, and then conclusion drawn of the model to foster promotion of solar rooftop power generation based on concreteness and sustainability.

3.3 Key Informants

The researcher selected experts by asking specialists to present the list of individuals (snow ball technique) who should be selected as experts. The questionnaire was also designed according to the problems found in the literature review.

The key informants were those involved in the promotion process of solar energy power generation in Thailand using the Delphi technique. There were 19 experts and into four groups: (1) Ten from the public sector, (2) Four from state enterprises and others, (3) Two from solar cell producing/installing/importing/and selling companies, and (4) Three producers from solar rooftop and sellers to MEA/PEA. The details are as follows:

1) Ten experts from seven government agencies

(1) Representative from The Energy Fund Administration Institute (Public Organization)

(2) Representative from Division of Solar Energy Development, Department of Alternative Energy Development and Efficiency

(3) Representative from Energy Policy and Planning Office (Energy Conservation and Renewable Energy Policy Bureau)

(4) Representative from Energy Policy and Planning Office (Power Policy Bureau)

(5) Representative from Office of Energy Regulatory Commission (Licensing Department)

(6) Representative from Pollution Control Department (Waste and Hazardous Substance Management Bureau)

(7) Representative from Department of Industrial Works (Industrial Waste Management Division)

2) Four experts from state enterprises and other agencies

(1) Representative from Electricity Generating Authority of Thailand (EGAT)

(2) Representative from Provincial Electricity Authority (PEA)

(3) Representative from Metropolitan Electricity Authority (MEA)

(4) Representative from Energy for Environment Foundation (EforE)

3) Two experts from producing, importing, selling, and installing companies of solar energy technology

4) Three power producers of solar rooftop (general public) and sellers of electricity to MEA/PEA

3.4 Research Tools

Tools used to collect data

1) Open-ended interviews with experts. Data were collected on the operation of solar rooftop power generation from relevant documents, previous research, and articles. This was used to construct questions to interview experts.

The questions were summarized into the following issues:

(1) What do you consider of the current promotion of solar rooftop? Should the public sector support the installation of solar rooftop?

(2) Can Thailand use the solar cell technology efficiently, covering all areas?

(3) What is your view of regulations of solar rooftop installation?

(4) How do you consider the installation of solar rooftop in terms of the positive and negative impacts on power consumers, the society, and the country?

(5) Will you install solar rooftop? Why or why not?

(6) Do you consider the technology for solar rooftop power generation to be appropriate for current power generation? Does the operation pose difficulties or not?

(7) Do you consider the grid system of MEA and PEA to be ready for solar rooftop power generation?

(8) Should EGAT improve the system or how should EGAT prepare for power generation from renewable energy?

(9) Do you consider that the license request for the current solar rooftop power generation project entails any problems and obstacles? How?

(10) What are the factors that can motivate you to produce power from solar rooftop?

Details shown in Appendix A.

2) Rating Scale questionnaire compiled all experts' views of the questionnaire in Round 1 to construct the Rating Scale questionnaire and returned it to the same experts.

Details shown in Appendix B.

3) Rating Scale questionnaire compiled all experts' views of the questionnaire in Round 2 to construct the Rating Scale questionnaire in Round 3 and returned it to the same experts.

Details shown in Appendix C.

4) The evaluation form of the draft model was given to the experts from relevant agencies for comments in order to recommend the complete model.

Details shown in Appendix D.

3.5 Data Analysis

This research conducted data analysis in two parts. The first part consisted of data analysis from the Delphi technique using the descriptive statistics such as statistics, interquartile range, and median. The consistency criteria of the experts' views were as follows:

1) Interquartile Range (Jatupong Kaeosai, 1997)

0.01-0.99 = very highly consistent experts' views

1.00-1.50 = highly consistent experts' views

1.51 upward = low or no consistent experts' views

2) Median was the value of the data with the position in the middle to investigate views of the experts with the scores at the median position in each question of the rating scale questionnaire.

Based on the rating scale questionnaire of five levels, the researcher gave the weighted scoring as follows:

5 = Trend of the most probability

4 = Trend of much probability

3 = Trend of medium probability

2 = Trend of little probability

1 = Trend of the least probability

The median obtained from the answers of all experts could be translated according to the researcher's criteria as follows:

Median of 4.50 upward = experts viewed that the message was the most probable

Median between 3.50-4.49 = experts viewed that the message was highly probable

Median between 2.50-3.49 = experts viewed that the message was fairly probable

Median between 1.50-2.49 = experts viewed that the message was little probable

Median lower than 1.50 = experts viewed that the message was the least probable (Penporn Chainapong, 1993)

In summary, based on the median of the experts' views, it was feasible to promote solar rooftop power generation. The interquartile range of the experts' views was also highly congruent in order to be used to construct the model.

The second part was the analysis of the expansion of the informal solar electricity to study power generation outside the government's supervision using the solar panel import data into Thailand (trade database of Ministry of Commerce and Customs Department, 2002-2019) in order to consider the trend of power generation form solar energy in the future. The analysis would show Thailand's solar energy production capacity, and production capacity inside and outside the system. Analysis was also conducted on the promotion of solar rooftop power generation in the past to apprehend the linkage of promotion of solar rooftop power generation both inside and outside the system in order to improve the promotion process. Later, the researcher used the factors to promote solar rooftop power generation and the results of analysis to expand power generation of informal solar electricity to conduct SWOT Analysis and conduct analysis with TOWS Matrix to prepare the (draft) model in order to estimate the probability and effectiveness of the draft. Therefore, there was no evaluation of the draft model by those responsible for promotion of solar rooftop power generation to prepare the model of appropriate promotion in line with Thailand's context.

3.6 Appropriateness and Implementation of the Model

The assessment of the appropriateness and implementation of the model was conducted by experts from five agencies related to solar rooftop power generation as follows:

1) Electricity Generating Authority of Thailand
2) Metropolitan Electricity Authority
3) Provincial Electricity Authority
4) Department of Alternative Energy Development and Efficiency, Ministry of Energy
5) Private rooftop solar panel installation companies

The congruence, linkage, and feasibility of the model to promote solar rooftop power generation was taken into consideration. Consideration was also taken of the efficiency and effectiveness of the model. Moreover, feasibility for utilization of the model was considered to serve as the guideline to formulate policy or construct a model to promote solar rooftop power generation in the future.

CHAPTER 4

RESULTS

The study investigated the factors promoting solar rooftop power generation, the expansion of informal solar power registration with government agencies, as well as recommending a model for the promotion of solar rooftop power generation. The research is divided into three parts. Part 1: Factors promoting solar rooftop power generation utilizing the Delphi technique. Part 2: Analysis of the expansion of informal solar electricity registration with government agencies. Part 3: Model for the promotion of solar power generation in the future. The study result in Part 1 Factors that could motivate more producers of rooftop solar energy to register with authorities. The study result in Part 2 was analyzed to reduce the gap or obstacles to registration in line with the context of Thailand's energy promotion and the framework of Ministry of Energy's operation, as well as responsibilities of related agencies, and support of the factors as in Part 1, as well as policies, strategies, and plans related to the promotion of solar rooftop power generation with SWOT Analysis and TOWS Matrix in order to construct a model in Part 3. The details are as follows:

4.1 Analysis of Policies, Strategies, and Plans Related to Solar Rooftop Promotion

The researcher conducted the analysis of policies, strategies, and plans related to the promotion of solar rooftop power generation in order to study the congruence and operation of the promotion of solar rooftop power generation, and then the analysis of the feasibility/problems and obstacles in implementing the policies/plans impacting the achievement of goals in Thailand, consisting of the following:

4.1.1 Draft Alternative Energy Development Plan 2018-2037 (AEDP2018) increases production capacity of solar power to 1,000 MW and retains the goal of the share of the use of alternative energy per the use of final energy for not less than 30% in 2037, however, the operational framework is not clearly determined each year.

4.1.2 Thailand Smart Grid Development Master Plan 2015-2036 determines the use of SMART GRID system for management of power consumption and enables power users to have a role in power generation (Prosumer), providing the opportunity for power users to efficiently manage the use of electricity appropriate to their lifestyle and behavior of power consumption.

4.1.3 Policy to purchase electricity from renewable energy in the form of Adder by which the government purchases electricity from renewable energy at the rate of 8 baht/unit for the duration of 10 years. The purchasing prices of electricity will fluctuate following FiT and FiT has high fluctuations.

4.1.4 Policy to purchase electricity from renewable energy in the form of FiT by which the government purchases electricity at different rates based on the types of technology of renewable energy and the size of the electric generator for the duration of 25 years. The pricing fluctuations of electricity purchasing are small, enabling more stable pricing of electricity purchasing than the Adder.

4.1.5 Power Development Plan 2018-2037 (PDP2018) promotes solar power generation and supports the expansion of transmission and distribution systems of EGAT, PEA, and MEA.

4.1.6 15-Year Renewable Energy Development Plan 2008-2022 determines the increased share of the use of renewable energy at 20% of the country's use of final energy in 2022. If there is motivation and integration of cooperation among relevant agencies to amend the laws to accommodate solar power generation, the objectives and the goals of this plan will be reached.

4.1.7 12th National Economic and Social Development Plan by increasing the potential of management, production, and consumption of renewable and clean energy through the development of information management system and consumption of renewable energy, assessment of measures and mechanism to promote power generation from renewable energy in the form of FiT in order to develop and improve other forms of promotion.

4.1.8 Draft Energy Efficiency Plan (EEP2018) aims to reduce 30% of Energy Intensity (EI) by 2037. At present, combined measures are used, including Push with supervising measures through Energy Conservation Promotion Act B.E. 2535 (1992) and B.E. 2550 (2007) (amended) in parallel with Pull factors with financial measures through promotion, assistance, and support from Energy Conservation and Promotion Fund.

The details are as follows:

Table 4.1 Policies, Strategies, and Plans Related to Promotion of Solar Rooftop Power Generation

Policies/plans	**Main points promoting solar rooftop power generation**	**Analysis of policies/plans**
4.1.1 Draft Alternative Energy Development Plan 2018-2037 (AEDP2018)	Increase solar power generation capacity from 6,000 MW to 10,000 MW Increase community power plant project to allow grassroot economy to come into the system between 2020-2024 totaled 1,933 MW from biomass fuel, biogas from wastewater, biogas from energy crop, and solar hybrid by retaining the goal of the share of renewable energy consumption per final energy of not less than 30% in 2037 and retaining the goal to purchase electricity from renewable energy of 18,696 MW.	No operational framework is clearly determined each year
4.1.2 Thailand Smart Grid Development Master Plan 2015-2036	Apply the SMART GRID system to manage the use of electricity with communication technology. SMART GRID will calculate production capacity from fossil fuel and renewable energy similarly to the same power plant and in accordance	With the SMART GRID system, electricity users will assume a role in power generation (Prosumer). Electricity users are given the opportunity to efficiently manage

Policies/plans	Main points promoting solar rooftop power generation	Analysis of policies/plans
	with the actual consumption. It is also designed to accommodate power generation scattered sources, affecting solar power generation.	electricity consumption as appropriate to their lifestyle and behavior of electricity consumption. A great deal of information is exchanged between various devices. Coordination between measuring equipment, data processing, automation, and data communication to ensure the country's efficient electricity management. At present, the use of SMART GRID system has been tested in some provinces.
4.1.3 Policy to purchase electricity from renewable energy in the form of Adder	The government purchases electricity at the rate equal to Adder based on the types of RE together with regular pricing of electricity purchasing which fluctuates following overall costs of the country's electricity generation which tends to increase on a continuous basis. The pricing rate of purchasing with Adder is 8 baht/unit for the duration of 10 years.	Can attract a great number of investors in RE during the first 3 years of the announcement of the use of Adder system (2007-2009). As for the measure for electricity purchase with Adder, the pricing of electricity purchasing will fluctuate following the FiT and the FiT experiences high fluctuations.
4.1.4 Policy to purchase electricity from renewable	Government purchases electricity at different rates based on the types of renewable energy technology that is used and size of electric generator.	As for the measure for electricity purchase with FiT, the pricing of electricity purchasing will

Policies/plans	Main points promoting solar rooftop power generation	Analysis of policies/plans
energy in the form of FiT	FiT prices include the following: for household ≤ 10 kWp 6.85 baht/unit, business/factory >10-250 kWp 6.40 baht/unit, business/factory >250-1,000 kWp 6.01 baht/unit for the duration of 25 years.	fluctuate according to the core inflation as announced by the Bank of Thailand. The increased pricing undergoes annual review. As a result, the fluctuations are low and therefore more stable than the Adder measure.
4.1.5 Power Development Plan 2018-2037 (PDP2018)	Focus on the development of renewable energy for its full potential in each area through promotion of solar power generation and expansion of transmission and distribution systems of EGAT, MEA, and PEA to support the promotion of area-based renewable energy as well as the development of Smart Grid system to increase efficiency in power generation from renewable energy.	Take into account new technologies including Smart Grid Disruptive Technology Prosumer and EV. Power plants are divided into regions while the base power plants will supervise security, with the renewable energy. However, the existing basic network cannot purchase electricity produced by people because the transmission line is one-way. Basic network must be improved to support production by expanding transmission line to accommodate renewable energy, as well as production of community power plant. Grid Modernization must also

Policies/plans	Main points promoting solar rooftop power generation	Analysis of policies/plans
		involve minor and main transmission lines.
4.1.6 15-Year Renewable Energy Development Plan 2008-2022	Increase the share of the consumption of renewable energy to 20% of the country’s consumption of final energy by 2022.	The appropriate promotion of production and consumption of renewable energy in terms of incentive measures, tariffs and investment measures, integration of cooperation among relevant agencies to amend the laws that will facilitate solar power generation, transfer of technical knowledge on solar power generation, and people sector’s participation in generation of renewable energy. This is done in parallel with promotion of research and development in efficient solar energy technology with ability to generate more electricity while reducing costs which will attract the consumption of renewable energy and increase the share of the consumption of renewable energy to reach the set goals.

Policies/plans	Main points promoting solar rooftop power generation	Analysis of policies/plans
		At present, BOI investment incentives cover only renewable energy industry. Thus, there should be provision of soft loan for power generators from solar rooftop.
4.1.7 12th National Economic and Social Development Plan	Part 4 Strategy of national development Strategy 7 Development of basic infrastructure and logistic system Goal 4 Energy development increases potential in management, production, and consumption of renewable energy and clean energy by developing the system of information management on production and consumption of renewable energy, assessment of measures and mechanism to promote power generation from renewable energy in the form of FiT to develop and improve other forms of promotion. This takes into account appropriate and fair costs both for producers and consumers and constructs mechanisms to participate in planning between the public and the private sectors to encourage the production and consumption of renewable energy and alternative energy in accordance with the goals	The integration of work between relevant agencies of all sectors will encourage energy security, increase efficient use of energy, and promote consumption of renewable and clean energy.

Policies/plans	Main points promoting solar rooftop power generation	Analysis of policies/plans
	of the renewable energy and alternative energy development plan from provision, preparation of raw materials, transport, system, management, to production of final energy, and continuous R&D in renewable energy technology such as solar energy. Part 4 Strategies for national development Strategy 9 Regional, urban, and economic zone development by increasing the potential of renewable energy production in central and lower northeast by promoting more renewable energy production with practical technology from solar energy in communities and local areas.	
4.1.8 Draft Energy Efficiency Plan (EEP 2018)	The draft EEP 2018 retains the goal to reduce 30% of Energy Intensity (EI) by 2037 compared to 2010 with the ability to reduce energy consumption ktoe via three strategies, namely, compulsory strategy of rules and regulations, promotional strategy of financial measures, and supporting strategy of personnel development, R&D.	At present, combined measures are used, including Push with supervising measures through Energy Conservation Promotion Act B.E. 2535 (1992) and B.E. 2550 (2007) (amended) in parallel with Pull with financial measures through promotion, assistance, and support from Energy Conservation and

Policies/plans	Main points promoting solar rooftop power generation	Analysis of policies/plans
		Promotion Fund. It is expected to save the country's energy between 2018-2037 total 54,371 ktoe or approximately 815,571 million baht will be saved, reduce power plants for approximately 4,000 MW, and reduce carbon dioxide emission by approximately 170 Mt-CO_2.

Based on Table 4.1, it can be summarized that the relevant policies and plans play a major role in promoting solar rooftop power generation. The various plans focus on increasing the share of the consumption of renewable energy through compulsory and motivating measures, the development of the system of information management and smart grid network system, and expansion of transmission system to ensure efficient management. The assessment of measures and mechanism is determined to promote power generation from renewable energy in the form of FiT to develop and improve other forms of promotion. Concurrently, R&D is also promoted for solar energy technology in tandem with cooperation between the public and private sectors in the production and the consumption of renewable energy.

4.2 Factor Promoting Solar Rooftop Power Generation in Thailand

At present, many countries realize the importance of power consumption that has a low impact on the environment. Consequently, policies have been formulated to promote the increased use of alternative energy. Thailand has also formulated policy to promote the use of alternative energy as appeared in the draft AEDP 2018. In order to create the incentives and drive the production of solar energy according to the objectives, study should be conducted on the promotion of solar rooftop power generation to serve as a practical guideline according to the management principles of efficient projects or policies. The three rounds of data collection based on the Delphi technique revealed that the median of the responses of the experts in the final round was over three which meant that the experts thought that the factors derived from the study had the feasibility at fair to the highest level to promote solar rooftop power generation and the interquartile range equaled 1.00 which meant that the experts' views were highly congruent. The researcher therefore established the factors promoting solar rooftop power generation under the framework of the CIPP-I Model consisting of Context, Input, Process, Product/Outcome, and Impact. The results are shown in Table 4.2.

Table 4.2 Results based on the Delphi Technique using Descriptive Statistics

Issues		Suitability/Feasibility		
		Mdn.	**IR.**	**Consideration**
Context	Growth of electricity demand in urban areas/Growth of cities and towns/Urban population	5	1	Yes
	Electricity price/Oil price	5	1	Yes
	Growing opposition to new electricity plant	4	1	Yes
	Solar equipment becomes cheaper/through advance in technology	4	1	Yes
	Rich exposure to solar light	4	1	Yes
	AEDP/Policies/Laws/Regulations / Incentives	4	1	Yes

Issues		Suitability/Feasibility		
		Mdn.	**IR.**	**Consideration**
Input	Social innovation /Awareness/ Understanding	4	1	Yes
	Active household participation	3	1	Yes
	Solar equipment supplies/Equipment quality assurance	4	1	Yes
	Certification of equipment standards/Certification of private installer personnel-skill training	4	1	Yes
Process	Grid code control electricity stability/Power bank system	4	1	Yes
	MEA/PEA facilitation of smart grid	3	1	Yes
	Control of power ripple/Fluctuation (surge/drop)/Data collection/Data processing/System self-correction	3	1	Yes
Product/ Outcome	Amplification of solar electricity production	4	1	Yes
	Increased share of renewable clean electricity	4	1	Yes
	Increased power generation efficiency	3	1	Yes
	Reduced power loss	4	1	Yes

Issues		Suitability/Feasibility		
		Mdn.	IR.	Consideration
Impact	Reduced needs for new power plant	4	1	Yes
	Power stability/Diversification	4	1	Yes
	Increased employment	4	1	Yes
	Increased use of domestic resources (sunlight)	4	1	Yes
	Good international image/Clean environment/Gaining public appreciation/Acceptance	4	1	Yes
	Increased economy of scale	4	1	Yes

Note: IR = Interquartile Range, Mdn. = Median

Round 1: The issues were summarized using open-ended interviews. The broad questions covered the problems addressed by this research. The factors promoting solar rooftop power generation in Thailand are summarized in Table 4.3.

Table 4.3 Factors of Promotion of Solar Rooftop Power Generation in Thailand

Issues	Definitions
Context	
- Growth of electricity demand in urban areas/Growth of cities and towns/Urban population	Growth of electricity demand in urban areas: Cities with facilities and basic infrastructure system driven by electricity, resulting in more demand for electricity than in rural areas. Growth of cities and towns: More growth of urban communities, progress in public utilities increasing space of

Issues	Definitions
	urban communities, and resulting in higher use of electricity.
	Urban population: Urban residents required new technology for accommodation. Solar rooftop was therefore an alternative energy that could save electricity fees.
- Electricity price/oil price	Electricity price: Costs of renewable energy tended to be lower than EGAT's electricity prices.
	Oil price: Costs of renewable energy tended to be lower than oil price, the country's main energy source.
- Growing opposition to new electricity plant	Growing opposition to new electricity plants which were fossil-powered not accepted by the public whereas the public accepted solar power generation more
- Solar equipment becomes cheaper/through advance in technology	Solar equipment becomes cheaper: Cheaper solar equipment would motivate the public to take interest in producing more solar energy, enabling access from all groups.
	Technological advancement: Solar technological advancement could be an efficient alternative for power generation at present.
- Rich exposure to solar light	Physical features affecting exposure to solar light with Thailand's rich

Issues	Definitions
	exposure to sunlight, enabling large volumes of power generation.
- AEDP/Policies/Laws/ Regulations/Incentives	AEDP: Clearly formulated framework each year.
	Policies: Appropriate and continuous promotion policies.
	Laws: Clear controlling and supervising laws.
	Regulations: Uncomplicated regulations on the installation of solar rooftop power generation.
	Incentives: Stimulation and incentive measures that could attract more solar rooftop power generation.
Input	
- Social innovation/Awareness/Understanding	Social innovation: Solar energy socially innovative that could be applied to various tasks.
	Awareness: Public was aware of the present situation of electricity consumption and generation of clean energy.
	Understanding: Public understood alternative energy, resulting in more demand for solar-related technology for power generation.
- Active household participation	Household sector could produce power from solar rooftop for own consumption or sale to EGAT.

Issues	Definitions
- Solar equipment supplies/Equipment quality assurance	Solar equipment supplies: If the prices of solar energy were not high, the general public would have more access to solar rooftop power generation. Equipment quality assurance: Equipment quality assurance would create more confidence in terms of efficiency and safety for the system of solar rooftop power generation.
- Certification of equipment standards/Certification of private installer personnel-skill training	Certification of equipment standards: Solar equipment with standard certification enabled consumers' inspection. Certification of private installer personnel-skill training: Installers attended skill trainings for system installation with certification to foster more confidence and acceptance of solar power generation.
Process	
- Grid code control electricity stability/Power bank system	Grid code control electricity stability: EGAT had grid code control electricity stability. Power bank system: Development of efficient power bank system at affordable prices, resulting in promotion of more sustainable solar power generation
- MEA/PEA facilitation of smart grid	MEA/PEA facilitation of smart grid would motivate the public to take more

Issues	Definitions
	interest in solar rooftop power generation.
- Control of power ripple/Fluctuation (surge/drop)/Data collection/Data processing/System self-collection	Control of power ripple: The country's electricity system could reduce power ripples produced from alternative energy. Fluctuation (surge/drop): The country's electricity system could reduce the fluctuation from surges or drops of electricity produced from renewable energy. Data collection: EGAT collected data on the quality of electricity to serve as data for the system installation of solar rooftop power generation. Data processing: EGAT was equipped with data processing of quality of electricity for analysis and solutions to problems in the areas. System self-correction: Smart grid system was used for electricity management.
Product/Outcome	
- Amplification of solar electricity production	Growth of solar energy industry could create opportunity for more access to the system installation.
- Increased share of renewable clean electricity	The public required environmental-friendly energy and increased share of renewable energy. Therefore, more

Issues	Definitions
	people were interested in solar rooftop power generation.
- Increased power generation efficiency	Could respond to the needs of energy in various areas and cost-effectiveness or wherever there was power consumption, there was power generation.
- Reduced power loss	Solar rooftop power generation entailed power consumption in the areas of power generation and reduced power loss in transmission line system.
Impact	
Economic	
- Increased economy of scale	Investment in renewable energy so that the public could install the system of solar power generation on a wide scale.
Social	
- Reduced need for new power plants	Solar power generation reduced the need for new coal-fired power plants opposed by the public.
- Increased employment	Solar power generation increased employment from system installation and related businesses.
- Power stability/Diversification	Power stability: Solar power generation could reduce the import of energy and fuel for use in power generation. Diversification: Increase energy alternative for more diversification.

Issues	Definitions
- Good international image/Clean environment/Gaining public appreciation and acceptance	Good international image: Use of solar energy reflected concern for the environment. Clean environment: Solar power generation was clean energy with low environmental impact. Gaining public appreciation and acceptance: As it did not cause pollution, it was accepted and widely used by the public.
Environmental	
- Increased use of domestic resources (sunlight)	Could use sunlight found everywhere for power generation in daily lives.

Round 2 Rating Scale Questionnaire was used to investigate the level of views of the experts, whether the scores were more or less in the middle position of each question of the rating scale questionnaire, which the researcher determined in five levels. The findings revealed the following.

Context: The experts commented that electricity demand in urban areas or expansion of urban communities, communities, and population were major factors promoting solar rooftop power generation due to the demand of electricity consumers, the high fuel prices for power generation, and the current opposition to electricity plants were the important factors at the highest level with 68.42%, 63.15%, and 47.36%, respectively. The government's formulated plans, policies, relevant rules and regulations, process of license application, and cheaper solar power equipment, as well as Thailand's rich exposure to solar light contributing to good power generation were the important factors at high level with 63.15%, 57.89%, and 42.10%, respectively, and motivated more installation of solar rooftop.

Input: Project operators should have knowledge and understanding of technology, regulations, processes to participate in the project; System installing companies passed the standard certification of the operation as the important factors at high level or 68.42% and 63.15%, respectively; People's participation in the use of renewable energy was the important factor at fair level or 57.89%; and installation price as one motivation for the installation of solar power generation and standard of the system installation was the important factor at the highest level or 42.10%.

Process: Implementation according to the grid code standard was the important factor at high level or 42.10%; MEA and PEA facilitation was the important factor at fair level or 57.89%; and control of power ripple with data processing system was the important factor at fair level or 63.15%.

Product/Outcome: Solar power generation entailed expansion, increased share of renewable energy, and reduced power loss in the transmission line system were the important factors at high level or 57.89%, 42.10%, and 47.36%, respectively; and solar rooftop power generation could increase the efficiency of power generation in the system as the important factor at fair level or 52.63%. These outcomes were the factors of promotion of solar rooftop power generation.

Impact: Solar power generation could reduce the need of a new power plant as the important factor at high level or 57.89%; Energy stability enhanced energy diversification, increased employment, utilization of existing solar energy as the important factors at high level or 42.10%, 47.36%, and 47.36%, respectively; Installation of solar rooftop made environment clean, enhanced good image and acceptance from the public as the important factor at high level or 42.10%; and economic growth as the important factor at high level or 63.15% to motivate solar rooftop power generation.

Round 3 Rating Scale Questionnaire: The researcher concluded as follows.

Context: The results of the collected views of the experts in Round 3 were slightly different on the issue of high fuel prices in power generation which the experts gave more weight to the scores of the factor as the important factor at high level or 68.42%. As for other issues, the experts had the same views as in Round 2.

Input: The results of collected views of the experts in Round 3 were not different. The experts had the same views as in Round 2.

Process: The results in Round 3 were slightly different. On the issue of MEA/PEA facilitation, the experts gave more weight to the scores of the factor as the important factor at fair level or 63.15%. As for other issues, the experts had the same views as in Round 2.

Product/Outcome: As for the results of collected views of the experts in Round 3, the experts' level of views slightly changed. The issues of solar power generation entailed expansion, increased share of renewable energy, and reduced power loss in transmission line system as the important factors at high level, similarly to Round 2.

Impact: As for the results of collected views of the experts in Round 3, there were slightly changed. On the issue of economic growth, the experts gave more weight to the scores of the factor as the important factor at high level or 68.42%. As for other issues, the experts had the same views as in Round 2.

Table 4.4 Conclusion of the factors promoting solar power generation with the Delphi technique based on the framework of CIPP-I Model

Round 1	Round 2	Round 3
	Context	
1. Growth of electricity demand in urban areas/ Growth of cities and towns/ Urban population 2. Electricity price/Oil price 3. Growing opposition to new electricity plant 4. Solar equipment becomes cheaper/through advance in technology 5. Rich exposure to solar light 6. AEDP/Policies/Laws/ Regulations/Incentives	The experts commented that electricity demand in urban areas or expansion of urban communities, communities, and population were major factors promoting solar rooftop power generation due to the demand from electricity consumers, the high fuel prices for power generation, and the current opposition to electricity plants were the important factors at the highest level with 68.42%, 63.15%, and 47.36%, respectively. The government's formulated plans, policies, relevant rules and regulations, process of license application, and cheaper solar power equipment, as well as Thailand's rich exposure to solar light contributing to good power generation were the important factors at high level with 63.15%, 57.89%, and 42.10%,	The results of collected views of the experts in Round 3 were slightly different. On the issue of high fuel price for power generation, they gave more weight to the scores of the factor as the important factor at high level or 68.42%. As for other issues, they had the same views as in Round 2.

Round 1	Round 2	Round 3
	respectively, and motivated more people to install solar rooftop.	
	Input	
1. Social innovation/ Awareness/Understanding 2. Active household participation 3. Solar equipment supplies/Equipment quality assurance 4. Certification of equipment standards/ Certification of private installer personnel-skill training	Project operator should have knowledge and understanding of technology, regulations, and processes in participating in the project; System installing companies were certified with standards for operation as the important factors at high level or 68.42% and 63.15%, respectively; People's participation in the use of renewable energy was the important factor at fair level or 57.89%; Installation price was also a motivation in installation of solar power generation and standards of the system installation was the important factor at the highest level or 42.10%.	The results of the collected views of the experts in Round 3 showed no change. They had the same views as in Round 2.
	Process	
1. Grid code control electricity stability/Power bank system 2. MEA/PEA facilitation of smart grid 3. Control of power ripple/ Fluctuation (surge/ drop)/Data collection/Data processing/System self-correction	Implementation according to the Grid code standards as the important factors at high level or 63.15% and 42.10%, respectively; MEA and PEA facilitation as the important factor at fair level or 57.89%; Control of power ripple and data processing system was the important factor at fair level or 51.89%.	The results of the collected views of the experts in Round 3 were slightly changed. On the issue of MEA and PEA facilitation, they gave more weight to the scores of the factor as the important factor at fair level or 63.15%. As for other issues, they had the same views as in Round 2.
	Product/Outcome	
1. Amplification of solar electricity production	Expansion of solar electricity production, increased share of renewable	The experts had the same views as in Round

Round 1	Round 2	Round 3
2. Increased share of renewable clean electricity 3. Increased power generation efficiency 4. Reduced power loss	energy, and reduced power loss in transmission line system were the important factors at high level or 57.89%, 47.36%, and 47.36%, respectively; Solar rooftop power generation increased efficiency of power generation in the system as the important factor at fair level or 52.63%. These outcomes constituted the factors to promote solar rooftop power generation.	2. They slightly changed the detail of their view of solar power generation stimulating growth and reduced energy loss in transmission line system as the important factor at high level as in Round 2.
	Impact	
1.Reduced needs for new power plant 2. Power stability/ Diversification 3. Increased employment 4. Increased use of domestic resources (sunlight) 5. Good international image/Clean environment/Gaining public appreciation/Acceptance 6. Increased economy of scale	Solar power generation reduced the needs for new power plants as the important factor at high level or 57.89%; Stability, increased energy diversification, employment, utilization of available solar light as the important factors at high level or 42.10%, 47.36%, and 47.36%, respectively; Installation of solar rooftop entailed clean environment, good image, and public acceptance as the important factor at high level or 42.10%; Economic expansion was the important factor at high level or 63.15% to stimulate solar rooftop power generation.	The results of the collected views of the experts in Round 3 were slightly different. On the issue of economic growth, they gave more weight to the scores of the factor as the important factor at high level or 68.42%. As for other issues, they had the same views as in Round 2.

Factors of promotion of solar rooftop power generation at present Based on the study using the Delphi technique, the factors promoting solar rooftop power generation at present could be summarized as follows:

4.2.1 Context

1) Growth of electricity demand in urban areas/Growth of cities and towns/Urban population: This was an important factor as a large number of public utilities accommodating daily lives require electricity to drive the system. Solar rooftop

power generation could therefore respond to the demand in urban areas. At present, urban communities experienced high growth or expansion. The cost-saving alternative of current urban residents was the installation of solar rooftop. It could be seen that housing estate businesses turned to more installation of solar rooftop.

2) Electricity price/Oil price: Technology for solar energy generation tended to be cheaper: Based on the current ex-works price of the average power generation and the ex-works cost of power generation based on the type of fuel from calculations using the data of IRENA, it was found that the production cost of solar power was 6.19 baht per unit (kWh) with the production share of 1.9%. (Project for environmental evaluation at the strategic level in the area for the establishment of coal-fired power plant in the south) (National Institute of Development Administration, 2020). If the electricity produced from solar power was cheaper than the electricity purchased from EGAT at present, it would stimulate more people to install solar rooftop.

3) Growing opposition to new electricity plants: Due to the present demand for electricity and opposition to new power plants, solar power generation could serve as an alternative to reduce power plant construction. Solar power generation could respond to the electricity demand during peak periods and as a clean energy with low impact on the environment and with public recognition.

4) Solar equipment became cheaper/through advances in technology: Cheaper prices of solar equipment would attract interested people to install more systems of solar energy generation. National Science and Technology Development Agency (NSTDA) conducted R&D on production of batteries with low costs for energy storage for people's own use. At present, NSTDA signed an R&D cooperation with Energy Absolute Public Company Limited for a period of five years (2020-2025) to increase competency of the function of energy storage equipment with high capacity (or battery) which was highly efficient and safe by reling on domestic resources and production. The R&D topic would focus on relevant advanced technolgy such as supercapacitor, zinc ion battery, lithium-sulphur battery, activated carbon from agricultural produces such as palm kernel shell; development of production process; and synthesis of graphene; as well as management cycle of functioning system of batteries for safety and high efficiency. The cooperation also consisted of the

establishment of the center of excellence of advanced batteries produced from domestic raw materials for security. Moreover, the Federation of Thai Industries in collaboration with Thailand Development Research Institute conducted a feasibility study and recommended the guideline to promote power backup industry for the country's grid energy storage (Thailand Development Research Institute, 2019)

5) Rich exposure to solar light: Situated in the tropical zone near the equator, Thailand is exposed to a great deal of sunlight. In Thailand, the average of sunlight intensity per square meter per day of various provinces was between 4.5-5.5 kilowatts-hour per square meter per day (4.5-5.5 kWh/sq.m./day) (Department of Alternative Energy Development and Efficiency, 2017c). Therefore, solar rooftop power generation could offer efficiency and reduce the problem of peak demand for electriciy in summer (peak season).

6) Renewable Energy and Alternative Energy Development Plan/Policies/Laws/Regulations/Incentives: AEDP had clearly determined the framework for each year with follow-up on the progress of actual installation, actual supply of electricity, appropriate policies on investment promotion (BOI), improvement of regulations and amendment of laws in accordance with the installation of solar rooftop power generation by reducing redundancies and complications in permit application with one stop service for services and incentives such as tax reduction for solar rooftop installers.

4.2.2 Input

1) Social innovation/Awareness/Understanding: The general public is currently aware of energy saving and use of energy with low impact on the environment. Solar energy technology was therefore an alternative for accepted use of energy as the technology was simple and easy to understand. At present, there has been energy-saving innovation such as hot water system from hybrid solar energy or solar roof tiles. Solar energy generation could therefore be applied to diverse tasks.

2) Active household participation: The general public wanted participation in power generation for own use or sale to EGAT as solar rooftop power generation could save household electricity costs. The sale of electricity into EGAT's system would generate household income.

3) Solar equipment supplies/Equipment quality assurance: This was one incentive for the installation of solar rooftop power generation. If the prices of solar equipment were not high, people would have the opportunity for more access. Concurrently, the equipment must have quality certification for both efficiency and safety.

4) Certification of equipment standards/Certification of private installer personnel-skill training: Consumers could inspect the standards of the equipment y themselves. Thus, there was confidence that each equipment was certified to a standard such as crystal light solar panel, silicon solar panel with the standard number IEC 61515 Crystalline Silicon Terrestrial Photovoltaic (PV) Modules-Design Qualifcation and Type Approval or TIS 1843, and thin film solar panel with the standard number IEC 61646 Thin-film Terrestrail Photovoltaic (PV) Modules-design Qualification and Type Approval or TIS 221 (Kraisorn Anchaleeworapun, 2012). The present issue was that the installation of solar rooftop power generation system did not meet the standards. In the future, if the installer possessed installation certification, it would attract increased interest in solar rooftop power generation.

4.2.3 Process

1) Grid code control electricity stability/Power bank system: Using the smart grid system for energy management to control electricity stability together with the development of the power bank system for efficient and cheap energy storage.

2) MEA/PEA facilitation of smart grid: This would promote more solar power generation as the overall use of electricity could be seen and the installation of transmission lines meeting the need of the general public.

3) Control of power ripple/Fluctuation (surge/drop) /Data collection/Data processing System self-correction: EGAT could reduce power ripple produced from alternative energy. Solar rooftop power generation into EGAT's electricity grid system would impact stability or regularity of the ripple such as bright sunlight alternating with no sunlight. If a great deal of electricity was used, there would be a power drop, prabably impacting the efficiency of the electricity use in the affected areas. Promotion of power generation from renewable energy should therefore be conducted in parallel with the development of a smart grid system for efficient

management of solar power, including data processing for speedy rectification of the system, and for stability in the areas around the solar rooftop installation.

4.2.4 Product/Outcome

1) Amplification of production of solar electricity: In 2018 there were 15 companies producing solar cells and solar panels and seven companies dealing in businesses related to solar power generation (Department of Alternative Energy Development and Efficiency, 2020). With higher growth of cell and solar panel manufacturing industries in Thailand, the installation of solar rooftop power generation systems will increasingly be available to the general public as a result of competition and the market mechanism.

2) Increased share of renewable and clean electricity: As solar energy is environmental-friendly, there would be no GHG emissons form power generation after installation and the beginning of operation. However, GHG would be emitted during the production of solar panels, transport, and disposal of solar panels at the end of life (National Institute of Development Administration, 2020) with no costs in the purchase of the fuel that will be depleted in the future. Thus, the general public is increasingly interested in solar rooftop power generation.

3) Increased power generation efficiency: As solar energy could be produced in all areas of Thailand, those living in remote areas could access electricity, resulting in consumption of electricity produced in the areas, considered as optimal consumption of energy (Wherever there was power consumption, there was power generation).

4) Reduced power loss in the system: Solar rooftop power generation in areas where there was electricity demand could reduce energy loss in the transmission line system.

4.2.5 Impact

1) Economic

Increased economy of scale: Solar power generation entails investment, resulting in the growth of a solar energy industry and enabling the general public to install the system on a wide scale. EPPO revealed that in 2019 consumption of the country’s primary energy experienced growth of 0.7% with the increase of the consumption of oil, natural gas, and alternative energy, in line with the country's GDP, which the Office of the National Economic and Social Development Council (NESDC) forecast growth of approximately 2.6%. This in accordance with the growth in investment and consumption of the private sector and the Dubai crude oil price at 62 USD/barrel (Energy Policy and Planning Office, 2020b).

2) Social

(1) Reduced need for new power plants: As solar power generation could respond demand for electricity, there was no need for new power plants.

(2) Increased employment: Solar power generation could widely generate employment. Based on the data of the Department of Industrial Works, in 2020 the employment rate per power generation of 1 MW of solar power plant equaled 1.5 (National Institute of Development Administration, 2020).

(3) Power stability/Diversification: Solar power generation could increase energy security, reduce imports of energy and fuel for electricity production, and provide diverse alternatives in energy consumption. In 2019, the import value of energy was down 14% equivilent to the import value of 1,053 billion baht. This was in the same direction as the oil prices as the import of crude oil constituted 61% of energy imports (Energy Policy and Planning Office, 2020a)

(4) Good international image/Clean environment/Gaining public appreciation and acceptance: As solar energy is clean energy and has a low environmental impact, solar power generation could therefore promote the image of energy consumption that would be internationally appreciated and recognized.

3) Environmental

Sunlight, as found everywhere, could be used for power generation. As solar energy is accessible by all, solar rooftop power generation was therefore the optimal use of this renewable energy source.

4.3 Summary of the Factors Impacting the Promotion of Solar Rooftop Power Generation According to the CIPP-I Model Framework

Context consisted of demand for electricity in urban areas/growth of cities or towns/urban population, electricity price/fuel price, opposition to new power plants, solar equipment becomes cheaper/through advance in technology, rich exposure to solar light, and AEDP/policies/laws/regulations/incentives.

Input consisted of social innovation/awareness/understanding, household participation, solar equipment supplies/equipment quality assurance, certification of equipment standards/training for skills in installation.

Process consisted of grid code control electricity stability/power bank system, MEA and PEA facilitation of smart grid, control of power ripple/fluctuation (surge/drop)/data collection/data processing/system self-correction.

Product/Outcome consisted of amplification of production of solar electricity, increased share of renewable energy, increased power generation efficiency, and reduced power loss.

Impact consisted of economic impact: economic growth; social impact: reduced demand of new power plant, increased employment, power stability/diversification, good image/clean environment, appreciation and acceptance from the public; and environmental impact: use of sunlight found everywhere to generate electricity.

Context
- Growth of electricity demand in urban areas/growth of city/towns/urban population
- Electricity price/oil price
- Growing opposition to new electricity plants
- Solar equipment becomes cheaper/through advance in technology
- Rich exposure to solar light
- AEDP/Policies/Laws/Regulations/Incentives

Input	Process	Product	Impact
- Social innovation/ awareness/ understanding - Active household participation - Solar equipment supplies/Equipment quality assurance - Certification of equipment standards/ Certification of private installer personnel-skill training	- Grid code control electricity stability/Power bank system - MEA/ PEA facilitation of smart grid - Control of power ripple/ fluctuation (surge/drop)/ Data collection /processing/system self-correction	- Amplification of solar electricity production - Increased share of renewable clean electricity - Increased power generation efficiency - Reduced power loss	- Reduced need for new power plants - Power stability/ diversification - Increased employment - Increased use of domestic resources (sunlight) - Good international image/ Clean environment /Gaining public appreciation/ acceptance - Increased economy of scale

Figure 4.1 Summary of the Factors Impacting the Promotion of Power Generation from Solar Rooftop According to the CIPP-I Model Framework

4.4 Analysis of the Growth of Informal Solar Electricity

The researcher studied the growth of informal solar electricity or the growth of solar electricity not registered with government agencies, meaning the installation of solar power generation systems for household use not registered with OERC, a supervisory agency. The researcher conducted an analysis of the import volume of solar panels into Thailand (Trade database of Ministry of Commerce and Customs Department between 2002-2019) with results shown in Table 4.5.

Table 4.5 Solar Cell Import Value (millions of baht) and Estimate of Marginal and Cumulative Capacity (megawatts)

Year	Import value (millions of baht)	Assumption			Estimate	
		Import price	Increased efficiency (watts)	Efficiency per baht	Marginal capacity (megawatts)	Cumulative capacity (megawatts)
[1]	[2]	[3]	[4]	[5]	[6]=[5]x[2]	[7]
2002	3,457	1,500	100	0.067	230	230
2003	4,189	1,500	108	0.072	302	532
2004	6,242	1,500	117	0.078	486	1,018
2005	7,408	1,500	126	0.084	624	1,642
2006	6,295	1,500	136	0.091	573	2,215
2007	5,815	1,500	148	0.098	572	2,787
2008	5,851	1,500	159	0.106	622	3,409
2009	4,077	1,500	172	0.115	468	3,877
2010	7,484	1,500	186	0.124	929	4,806
2011	19,779	1,500	201	0.134	2,655	7,461
2012	21,092	1,500	218	0.145	3,060	10,521
2013	23,990	1,500	235	0.157	3,762	14,283
2014	16,556	1,500	254	0.169	2,806	17,088
2015	20,752	1,500	275	0.183	3,801	20,890
2016	27,083	1,500	297	0.198	5,362	26,252
2017	27,822	1,500	321	0.214	5,954	32,206
2018	29,202	1,500	347	0.231	6,754	38,960
2019	30,072	1,500	375	0.250	7,518	46,478

Source: Customs Department (2020b).

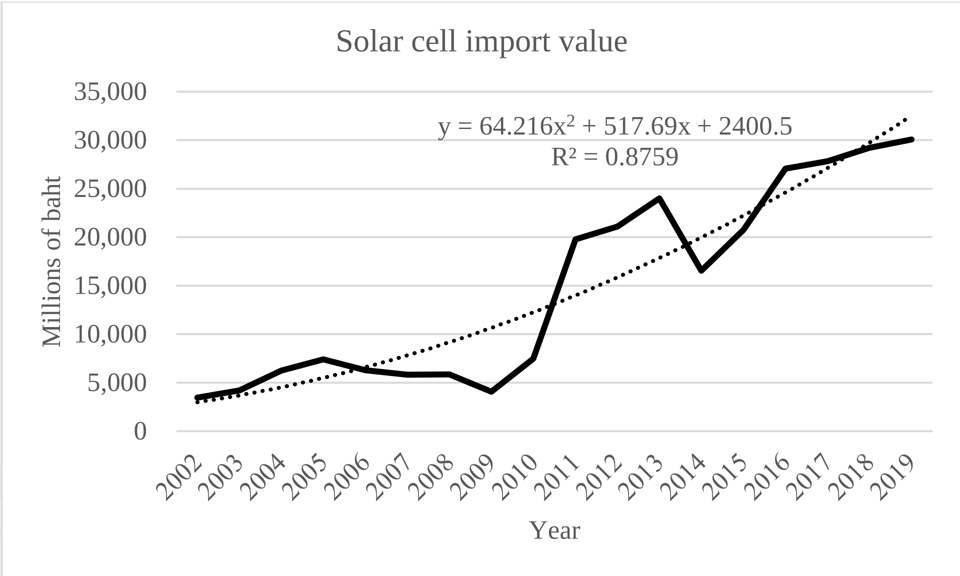

Figure 4.2 Import Value of Solar Cell (millions of baht)

From the equation $y = 64.216x^2 + 517.69x + 2400.5$

$R^2 = 0.8759$

When y = Import volume of solar panels

x = Number of years to import solar panels

R^2 = Decision coefficient

Table 4.5 reports the value of import of solar cells between 2002 and 2019 (column 2) and presents an estimate of marginal and cumulative capacity of solar electricity in column 6 and 7, respectively. The data on import value were retrieved from Thailand trading report. The import price in column 3 is an assumption that retail price is 3,000 baht for a 375 watts solar panel in 2019, twice the import price. It is assumed that the same 1,500 baht will buy a 100 watts solar panel in 2002. The increased efficiency in column 4 is assumed to be a constant of 8.08% per year, so that a 100 watts panel in 2002 becomes 375 watts panel in 2019. The efficiency per baht in column 5 is the ratio between increased efficiency and import price. The marginal capacity shown in Figure 4.2 is the product of efficiency per baht and import value, which gives the solar capacity of 230 megawatts for the import value of 3,457 million baht in 2002, and gives the solar capacity of 7,518 megawatts for the import value of 30,072 million baht in 2019. The cumulative capacity of solar electricity shown in Figure 4.3 is the sum of marginal capacity of solar electricity.

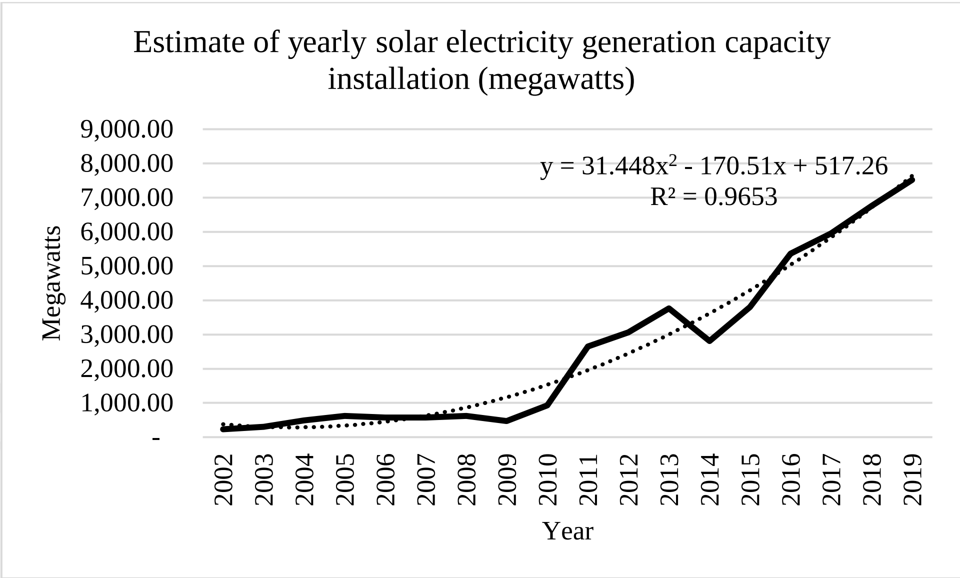

Figure 4.3 Estimate of Marginal Solar Electricity Generation Capacity Installation (megawatts)

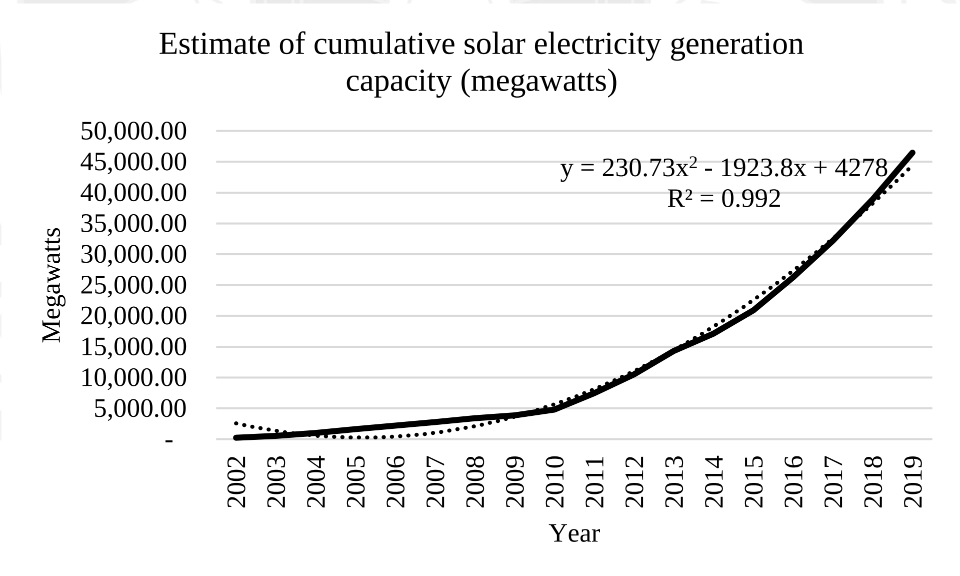

Figure 4.4 Estimate of Cumulative Solar Electricity Generation Capacity (megawatts)

The estimate of marginal solar electricity generation capacity installation (megawatts) shown in Figure 4.3 indicates a quadratic trend. Similarly, a quadratic trend is present for the estimate of cumulative solar electricity generation capacity (megawatts) shown in Figure 4.4.

Based on the import volume of solar panels in Thailand (Trade database of Ministry of Commerce and Customs Department between 2002-2019), analysis could be conducted to estimate the solar power generation for the full day and the solar power generation for the cumulative full day. As a result, the produced cumulative solar energy was known and the trend of solar power generation could be forecast to plan power generation in the future as shown in Table 4.6.

Table 4.6 Estimate of Total Full Day Solar Electricity Generation and Cumulative Total Full Day Solar Generation (megawatts)

Year	Import value (millions of baht)	Assumption				Estimate	
		Import price (baht)	Panel capacity (watts)	Full day generation (watts)	Full day generation per import price	Total full day generation (megawatts)	Cumulative total full day generation (megawatts)
[1]	[2]	[3]	[4]	[5]	[6]=[5]/[3]	[7]=[2]x[6]	[8]
2002	3,457	1500	100	462	0.308	1,065	1,065
2003	4,189	1500	108	499	0.333	1,395	2,459
2004	6,242	1500	117	540	0.360	2,246	4,705
2005	7,408	1500	126	583	0.389	2,881	7,586
2006	6,295	1500	136	631	0.420	2,646	10,233
2007	5,815	1500	148	682	0.454	2,642	12,875
2008	5,851	1500	159	737	0.491	2,873	15,748
2009	4,077	1500	172	796	0.531	2,164	17,912
2010	7,484	1500	186	861	0.574	4,294	22,206
2011	19,779	1500	201	930	0.620	12,265	34,471
2012	21,092	1500	218	1005	0.670	14,136	48,607
2013	23,990	1500	235	1087	0.724	17,378	65,985
2014	16,556	1500	254	1174	0.783	12,963	78,948
2015	20,752	1500	275	1269	0.846	17,562	96,510
2016	27,083	1500	297	1372	0.915	24,773	121,283
2017	27,822	1500	321	1483	0.989	27,507	148,790

Year	Import value (millions of baht)	Assumption			Estimate		
		Import price (baht)	Panel capacity (watts)	Full day generation (watts)	Full day generation per import price	Total full day generation (megawatts)	Cumulative total full day generation (megawatts)
[1]	[2]	[3]	[4]	[5]	[6]=[5]/[3]	[7]=[2]x[6]	[8]
2018	29,202	1500	347	1603	1.069	31,205	179,995
2019	30,072	1500	375	1733	1.155	34,733	214,728

Source: Customs Department, 2020b.

Table 4.6 presents the estimate of total full day solar electricity generation and cumulative total full day solar generation. Based on the data on import of solar cell and the assumption for import price, the computed full day solar electricity generation and cumulative total full day solar generation are presented in column 7 and 8, respectively. Column 4 presents the increased capacity of solar cell for the same 1,500 baht import price in column 3. The full day generation in column 5 is estimated based on 70% efficiency assumption by the quadratic equation for respective capacity in column 4. The quadratic equations for 100 watts and 375 watts solar panels are shown in Figure 4.5 and Figure 4.6. The computed marginal full day solar electricity generation (megawatts) and the computed cumulative full day solar electricity generation (megawatts) are presented in column 6 and 7, respectively, and Figure 4.7 and 4.8, respectively.

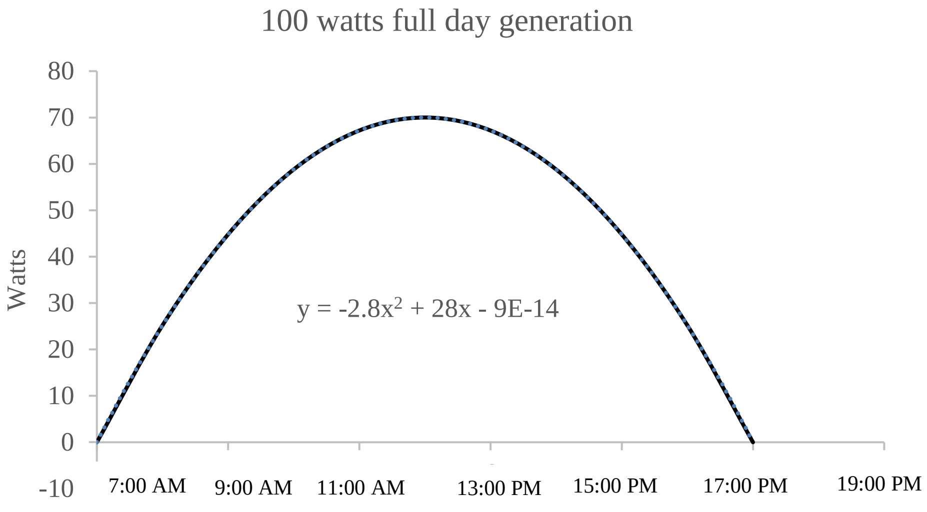

Figure 4.5 Full Day Solar Electricity Generation for 100 Watts Panel Assuming 70% Efficiency

From the parabola equation: $y = ax^2 + bx + c$

y = Power (Watts)

x = Time (hours)

a,b,c = Constant

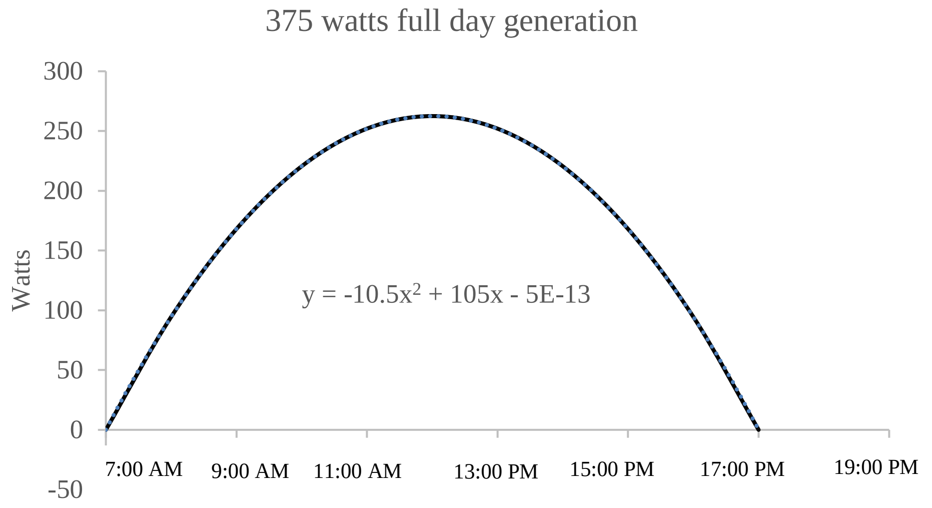

Figure 4.6 Full Day Solar Electricity Generation for 100 Watts Panel Assuming 70% Efficiency

Based on Figure 4.5 and Figure 4.6, power generation could be forecast from the installed capacity of solar power generation for each year in Thailand to formulate the plan for the overall management of power generation. The producers of solar energy for various activities could use the data to calculate the amount of electricity required for installation in order to generate sufficient electricity to meet the demand for electricity to drive any particular machine. However, the produced electricity also depended on other factors such as direction, angle for installation, terrain for installation, weather, and types of solar panels.

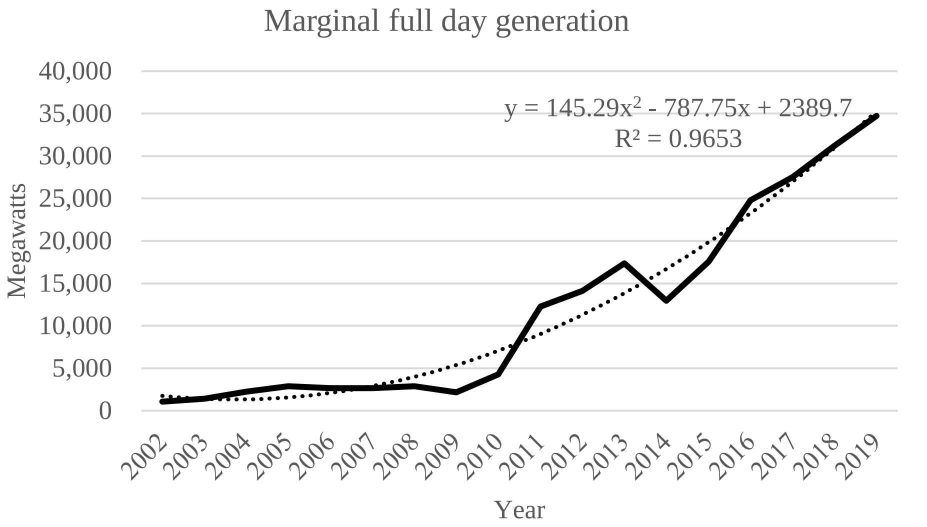

Figure 4.7 Marginal Full Day Solar Electricity Generation (megawatts)

From the equation $y = 145.29x^2 - 787.75x + 2389.7$

$R^2 = 0.9653$

When y = Full day solar power generation (megawatts)

x = Number of years of import of solar panels

R^2 = Decision coefficient

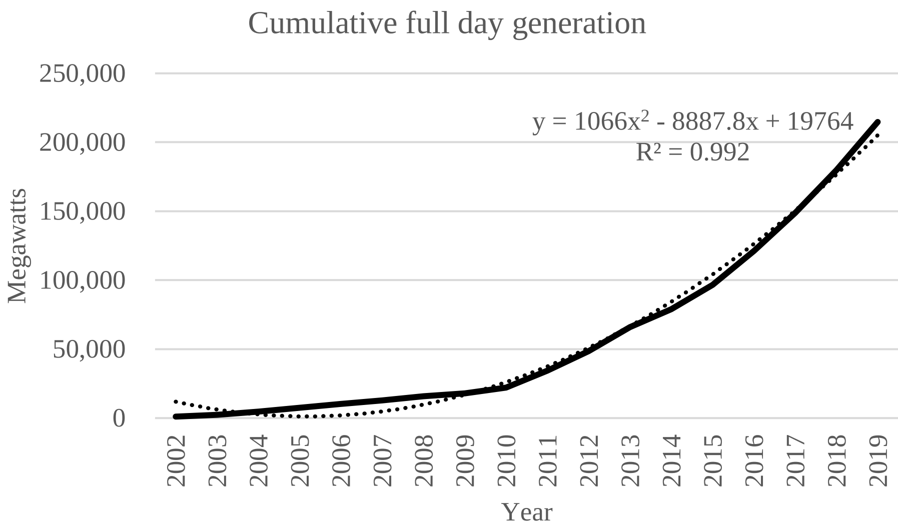

Figure 4.8 Cumulative Full Day Solar Electricity Generation (megawatts)

From the equation $y = 1066x^2 - 8887.8x + 19764$

$R^2 = 0.992$

When y = Cumulative full day solar electricity generation (megawatts)

x = Number of years of import of solar panels

R^2 = Decision coefficient

Figure 4.8 shows that Thailand can generate a higher amount of solar power every year with the trendline graph that is expected to increase. Based on the estimate of cumulative production capacity (megawatt) in Table 4.5, the forecast can be made of the amount of solar panels that are expired or are no longer cost effective for power generation in 25 years from now, totaling 166,991.58 MW, as shown in Figure 4.9. Power generation of 1 megawatt creates approximately 100 tons of waste, in total 16 million tons of waste. The study of Pichaya Rachdawong, Thitisak Boonpramote, Somchai Ratanathammaphan, David Banjerdpongchai, and San Sampattavanija (2016) forecast the amount of solar panels that began to be installed in Thailand since 2002 and would gradually not be cost effective from 2022-2058. The study found that the weight of solar panel waste would constitute approximately 626,301-794,840 tons. The main types of waste that would be generated from solar panels by 2045 included glass, aluminum, and copper. Glass would constitute approximately 195,403-286,475 tons of all types of panel while aluminum would be approximately 20,000-30,000 tons, and copper approximately 1,000-2,000 tons. As for lead which is hazardous to humans and the environment would become 134.2-198 tons of waste, and cadmium 0.65-0.95 tons. Department of Industrial Works, Ministry of Industry, forecast that in 5 years Thailand would generate expired solar panel waste as high as 500,000-600,000 tons and the trend would increase (Department of Industrial Works, 2019). The power generation of 1 megawatt with crystalline silicon solar panels would generate approximately 100 tons of waste while thin film solar panels would generate between 185-285 tons of waste, depending on the types of material.

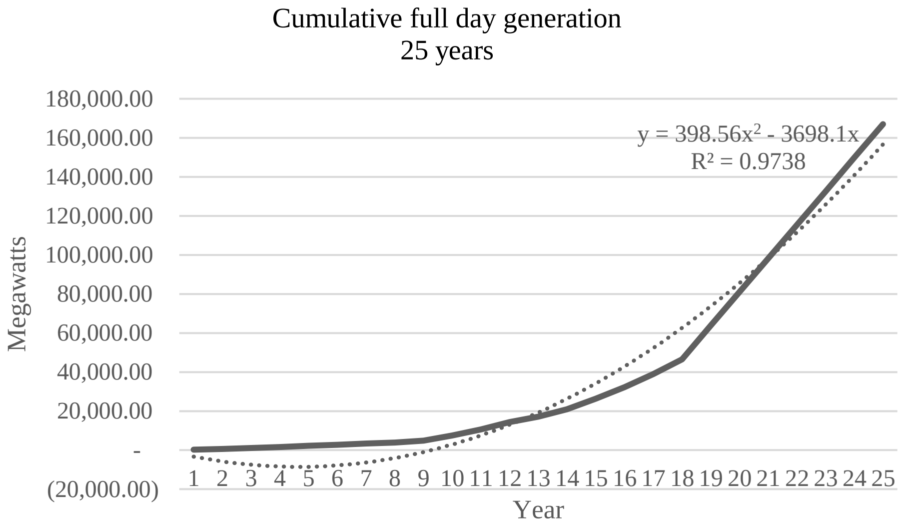

Figure 4.9 Cumulative Full Day Solar Power Generation (megawatts) in 25 Years

From the equation y = 398.56x2 – 3698.1x

R^2 = 0.9738

When y = Cumulative full day solar power generation (megawatts)

x = Number of years of import of solar panels

R^2 = Decision coefficient

Based on the calculation of the import of solar cells of Thailand between 2002-2019, it was found that Thailand had a cumulative installed capacity of solar cells totaling 46,478 MW. This showed that Thailand had a large amount of solar energy production capacity. Those registered solar power generation in the system equaled 2,935.019 MW (Office of Energy Regulatory Commission, 2020). Based on the report of the situation of solar power generation in Thailand between 2016-2017, the installed capacity of solar energy from solar rooftop of 2,067 residences in the system of MEA equaled 14.93 megawatts peak, 3,894 residences in the system of PEA equaled 32.12 megawatts peak, 96 business buildings/factories in the system of MEA equaled 36.05 megawatts peak, and 73 business buildings/factories in the system of PEA equaled 46.57 megawatts peak. In 2017, power from solar rooftop was generated for own consumption of 383 residences and/or business buildings/factories in the areas of PEA with the installed capacity of 224.48 megawatts peak and power from solar rooftop was generated for own consumption of 23 residences and/or business buildings/factories in the areas of MEA with the installed capacity of 5.06 megawatts peak (Department of Alternative Energy Development and Efficiency, 2017a). In 2019, Ministry of Energy and Energy Regulatory Commission operated a solar project for the general public with the aim to promote household electricity user installation at less than 10 kVA or installed capacity of not over 10 kWp in residences to be able to install the solar rooftop system for self-consumption. Their total installed capacity was only approximately 1 megawatt. The cumulative amount of solar rooftop power generation in the system of PEA and MEA totaled 360.21 megawatts peak. The export of solar cells between 2007-2019 totaled 2,315.98 MW (Customs Department, 2020a) as shown in Table 4.7.

Table 4.7 Export of Solar Cells between 2007-2019

Year	Export value (million baht)	Assumption: Increased efficiency (watts)	Assumption: Efficiency per baht	Estimate: Increased expenses or production costs per unit	Estimate: Cumulative production capacity (megawatts)
[1]	[2]	[3]	[4]	[5]=[4]x[2]	[6]
2007	324	148	0.098	31.81	31.81
2008	56	159	0.106	5.95	37.77
2009	59	172	0.115	6.80	44.57
2010	68	186	0.124	8.40	52.97
2011	44	201	0.134	5.85	58.82
2012	543	218	0.145	78.83	137.65
2013	972	235	0.157	152.38	290.03
2014	1,161	254	0.169	196.83	486.86
2015	1,170	275	0.183	214.35	701.21
2016	1,310	297	0.198	259.33	960.54
2017	1,819	321	0.214	389.22	1,349.76
2018	2,046	347	0.231	473.24	1,823.00
2019	1,972	375	0.250	492.98	2,315.98

Source: Customs Department (2020a).

It was found that informal solar energy constituted 41,227.001 MW or 88.70% which showed a large volume of solar power generation outside the system or informal solar electricity with no official reporting. However, the data survey of Ministry of Energy in 2015 revealed that most producers of solar panels imported raw materials for assembling such as cells, wafer panels, and raw materials for the aluminum structure. The survey used the reference from the database of Department of Industrial Works (2015), only for production and assembling of solar panels, excluding other equipment in the installation of electricity system. It was found that in Thailand there were 12 producers of solar panels with the combined production capacity of cells of 924 megawatts a year and the combined production capacity of solar panels of 4,009 megawatts a year, generating a total employment of 2,506 positions (Chariya Senpong, 2019).

According to the policy statement by General Prayut Chan-o-cha, Prime Minister, to the National Legislative Assembly on 12 September 2014, the government's policy on solar rooftop power generation is to promote the accomplishment of the goal to replace fossil fuel by at least 25% in 10 years. This was in accordance with Alternative Energy Development Plan: AEDP2015 (AEDP 2015) whereby the Ministry of Energy determined the goal to increase the share of the consumption of alternative energy for electricity energy, thermal energy, and biofuel under the AEDP2015 with 30% of the consumption of final energy in 2036 by determining the goal of solar power generation of 6,000 megawatts. This revealed the following observations:

EGAT lacked earnestness in promoting solar power generation due to conflict of interest. The empirical observations were as follows:

1) There were continual construction of new power plants such as the plan to construct a coal-fired power plant in the south of Thailand and plans to allocate new power plants in other regions rather than promotion of solar power generation. As alternative energy could not continuously generate power during the required time especially during the days without sunshine, there must be main power plants from fuels such as coal, natural gas, as well as the import of electricity from neighboring country to enhance the system's security or serve as backup power.

2) The determination of the criteria for permit application for solar power generation was complicated and involved many laws and regulations with many agencies so it was difficult to apply for a permit. The operation of the project to produce

solar energy from solar rooftop to sell electricity to MEA and PEA required the application of building modification permit (Aor 1). The buildings situated in the building control areas according to the Building Control Act required the building modification permit through inspection of the building control areas. They showed the plans of charts and roof structures, structure supporting solar cells, details of installation, list of calculations of structure and certification of engineers who designed and supervised civil work showing the plans of charts and roof structures, structure supporting solar panels, and details of installation in accordance with legal requirements and engineering principles. The permit to operate power plant (Ror Ngo 4) in case of installation of solar panels and invertors of the combined 5 horsepower or over 3.73 kW must follow the standards of the grid code on the criteria of design technique, technical details of electricity equipment and installation standards, and regulations related to the services of electricity grid system in order to provide the services of electricity grid system with smoothness and fairness, and not affecting other grid systems and users of other grid systems. The requirements of the electricity grid system determined the criteria and technical requirements of the operation of electricity grid system at the connection point of the grid system to avoid impact on security, safety, and quality of electricity in the grid system. A large number of requirements might limit the solar rooftop power generation for some groups of interested people.

3) Present the weakness of solar power generation such as fluctuation of solar power as a main issue as EGAT was responsible for maintaining the stability of electricity. Solar power generation in large volume might impact the overall electricity system. For example, in Australia there were a number of installations of solar rooftop, causing electricity fluctuation in the transmission line system. Australia’s main electricity producer, equivalent to Thailand’s EGAT (Mercer, 2019) suggested to cut the power supply from solar rooftop into the system in the event where there was too much electricity fluctuation in the transmission line system. Thus, EGAT seemed unenthusiastic about promoting solar rooftop power generation in terms of implementation but could not oppose the policy of renewable energy.

The researcher collected production capacity data on the solar energy of each country as the top five largest producers in 2019 (Germany, Japan, India, US, and China) and compared the solar energy per person in Thailand with them, using the data of the cumulative installed capacity between 2002-2019 to conduct analysis (International Renewable Energy Agency, 2020).

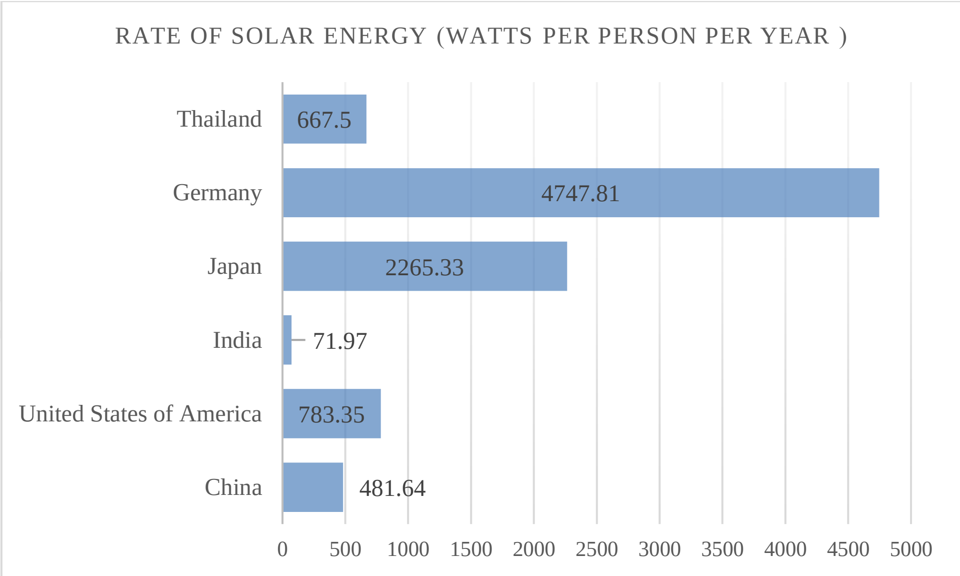

Figure 4.10 Watts per Person (International Renewable Energy Agency, 2020).

The study findings revealed that Germany had the highest watts per person of 4,747.81 watts/person/year thanks to effective planning and intensive promotion of both the public and private sectors. The government also stimulated interested businesspeople and companies to invest in renewable energy or own renewable energy, resulting in Germany being a leader in solar energy. It was followed by Japan, the number two solar energy producer in Asia, with the share of solar energy production of over half of the total production capacity of renewable energy, resulting in electricity per person equaling 2,265.33 watts/person/year. Whereas in US, based on the report of energy industry by Bloomberg New Energy Finance 2020, alternative energy experienced growth with electricity per person equaling 783.35 watts/person/year. Japan was followed by Thailand. Although the formal solar power production capacity in Thailand was low, the overall power production capacity not registered with government agencies was found to have the electricity per person of 667.50 watts/person/year which was considered high. China was the largest producer of solar energy in Asia with high electricity per person as well or equaling 481.64

watts/person/year. India was the number three producer of solar energy in Asia and aimed to produce 100 GW of solar energy by 2022. At present, solar energy is widespread in India with electricity per person of 71.97 watts/person/year as shown in Figure 4.10. If Thailand seriously promoted the use of solar power, it could respond to the public’s need for electricity and improve access to electricity in areas nationwide.

4.5 Model Promoting Solar Power Generation in the Future

For the model promoting solar power generation in the future, the researcher used the results of the analysis of policies, strategies, and maps related to the promotion of rooftop solar power generation in item 4.1. It was found that the government formulated plans and policies to promote solar energy generation but lacked clear timeframe in setting the production goal. The policies also lacked continuity and integration, as well as cooperation among relevant agencies. As a result, the promotion had little success. The factors of promotion acquired in item 4.2 provided the information of motivations in terms of Context, Input, Process, Product/Outcome, and Impact which attracted the system installation. The results of the analysis of the growth of informal solar electricity in item 4.3 provided the information of solar power production capacity in Thailand which could generate electricity only during the daytime. thus, import of electricity from neighboring countries was necessary to ensure electricity security. Moreover, the transmission network and energy management in Thailand were not yet developed to support power generation from renewable energy. The formal solar power generation might impact the stability of the overall system. Stakeholders should therefore prepare to set up a system to ensure efficient energy management. Study was also conducted on the development of energy storage systems with low cost that could respond to the needs of consumption during the periods with no sunlight. There was also relevant a literature review to conduct the SWOT analysis of the promotion of solar rooftop power generation, by conducting analysis under the 4M management concept and conducting an analysis of the opportunities and threats which were external factors for the promotion of solar rooftop power generation using PESTLE analysis as shown in Table 4.8.

Table 4.8 SWOT Analysis of Promotion of Solar Rooftop Power Generation

Strengths	**Weaknesses**
Man S1 Solar rooftop technology is a simple technology Money S2 Cheaper solar equipment Material S3 Solar rooftop technology can be diverse applications to social innovation Management S4 Growth of solar power generation, reduce import of fuel, and purchase of electricity from abroad S5 Increase share of renewable energy S6 Increase area for power generation by responding to the needs of energy in various areas nationwide S7 Reduce power loss in transmission line system S8 Forge household's participation S9 Public relations to campaign for energy saving and increased use of alternative energy	Man W1 No professional qualification standards of installers of the solar rooftop power generation system Money W2 Cheaper solar equipment but not accessible to all groups of people W3 High installation prices of solar power generation W4 Electricity produced from solar rooftop only during daytime W5 System must be put in place for electricity stability and energy storage system W6 Power ripple/fluctuation (surge/drop) and data collection/data processing/system self-correction Management W7 Installation of solar rooftop did not offer sufficient incentives W8 MEA and PEA facilitation of smart grid W9 Permit required many processes W10 No agency for management and control of disposal of solar panel waste
Opportunities	**Threats**
Political O1 Reduce needs for new power plant O2 Solar power generation enhanced energy stability/diversification O3 AEDP/policies of promotion on solar rooftop Economic O4 Solar power generation resulted in economic expansion Social	Political T1 Policy promoting solar rooftop lacked continuity Economic T2 At present, the purchase prices of electricity were much lower than in the past Social

Strengths	Weaknesses
O5 Solar power generation increased employment	T3 Acknowledgement of the public on the promotion of solar rooftop power generation was not widespread
O6 Demand for electricity in urban areas/growth of cities/urban population	Technology
O7 Opposition to new power plants	T4 Development/readiness of energy storage system
O8 The public accepted solar power generation	
Technology	Legal
O9 Trend toward cheaper costs of solar rooftop	T5 Many relevant laws and regulations on solar rooftop
O10 Technological advancement of solar rooftop power generation	Environmental
O11 Low impact on environment	T6 Regularity of acquired sunlight (during periods when sunlight was hidden by clouds)
Legal	
-	
Environmental	
O12 Thailand's sufficiently rich exposure to sunlight for solar rooftop power generation	
O13 Good image/clean environment	

The researcher used SWOT analysis of the promotion of solar rooftop power generation in Thailand to conduct an analysis of TOWS Matrix to formulate the solar rooftop power generation promotion strategies in more detail as shown in Figure 4.11.

TOWS Matrix	**Strengths** Man S1 Solar rooftop technology is a simple technology Money S2 Cheaper solar equipment Material S3 Solar rooftop technology can have diverse applications for social innovation S4 Create expansion of solar power generation, reduce	**Weaknesses** Man W1 Lack of quality assurance system of skill training for system installers Money W2 Cheaper solar equipment but not accessible to all groups of people W3 High prices for installation of solar power generation W4 Electricity produced from solar rooftop only during daytime

	import of fuel and purchase of electricity from abroad S5 Increase share of renewable energy S6 Increase area for power generation S7 Reduce energy loss in transmission line system S8 Forge participation of households S9 Public relations to campaign for energy saving and increased use of alternative energy	W5 System must be put in place to control electricity stability and energy storage system W6 Power ripple/fluctuation (surge/drop) and data collection/data processing/system self-correction Management W7 Installation of solar rooftop still lacked sufficient incentives W8 MEA and PEA facilitation of smart grid W9 Permit had many processes W10 No agency for management and control of solar panel waste disposal
Opportunities Political O1 Reduce need for new power plants O2 Solar power generation enhanced energy stability/diversification O3 AEDP/policies for promotion of solar rooftop Economic O4 Solar power generation resulted in economic expansion Social O5 Solar power generation increased employment O6 Demand for electricity in urban areas/growth of cities/urban population	(SO) (S2,O3,O4) Government must control the price mechanism for solar equipment to enable access for people of all sectors and with shorter payback period (S4,S8,S9,O1,O7,O8) Publicize policies and technology for the public to have knowledge and understanding of the value of solar power generation (S1,S3,O10) Arrangement for installers of solar rooftop power generation system to pass tests or training in	(WO) (W5,W6,W8,O2) The government sector was ready for electricity grid system and smart grid system, together with the system to control electricity stability to accommodate power generation from renewable energy (W5,W6,W8,O6,O10) Development of Grid Modernization (W9,O3,O4) One stop service or website that could link data with relevant agencies

O7 Opposition to new power plants O8 The public accepted solar power generation Technology O9 Trend toward cheaper cost of solar rooftop O10 Technological advancement of solar rooftop power generation Legal - Environmental O11 Increased use of domestic resources (sunlight) O12 Good image/clean environment	production and installation standards (S6,S7,S8,O1,O11) Establish the clear process of power generation for own use or power purchase/sale among themselves under the supervision of government agencies (ST) (S5,S6,S7,T4,T5) Promote R&D in technology such as solar roof tiles, power storage batteries	(W9,O3,O6,O8) Prepare Memorandum of Agreement with agencies related to promotion of solar rooftop power generation (W6,W7,W8,O3) Formulate action plan according to the policy framework of solar rooftop power generation promotion through participation process of stakeholders (W1,W5,W6,O2,O10) Establish ad-hoc agency responsible for control of installation of system to meet the standards through coordination with Thailand Professional Qualification Institute (W10,O3) Establish agency of management and control of disposal of solar panel waste (WT) (W7,T1) The government should continually formulate policy to promote solar rooftop power generation (W9,T5) Specific regulations to reduce redundancies of rules, regulations, and requirements (W4,W5,W6,W8,T6) Increase Grid Flexibility to accommodate power generation from renewable energy
Threats Political T1 Policy promoting solar rooftop lacked continuity T2 At present, prices for purchase of electricity are much lower than in the past Social T3 Acknowledgement of the public regarding the promotion of solar rooftop power generation was not widespread Technology T4 Development/readiness of energy storage system T5 Electricity produced only during daytime Legal T6 Many relevant laws and regulations Environmental		

T7 Regularity of acquired sunlight (during the periods when sunlight was hidden by clouds)		(W2,T2) Determine measures for the public's access to solar rooftop equipment (W9,T5) Review laws, regulations, and requirements related to concrete promotion (W8,W9,T1,T3) Develop management system through participation process of all sectors

Figure 4.11 TOWS Matrix of Solar Rooftop Power Generation Promotion in Thailand

The model promoting solar rooftop power generation in Thailand consisted of three operational processes as follows.

4.5.1 Policies

1) Forge participation in the formulation of action plan according to the policy framework to promote solar rooftop power generation through stakeholders' views in meetings held by EGAT, PEA, MEA, policy-making government agencies, SPPs, VSPP, and other bodies.

2) Promote power generation for own use or purchase and sale of electricity between themselves, for example, purchase and sale between houses or buildings, or between provinces with payment of fees for the use of transmission line system to the government.

4.5.2 Promotion

1) Develop the grid modernization system through cooperation with EGAT, PEA, and MEA in power transmission that communicates data with the smart electricity system, forecast and control of power generation from renewable energy (Renewable Forecast Center), as well as improve power plant for flexibility (Flexible Power Plant) to be able to timely increase capacity from main power plant during periods of a lack of renewable energy and arrangement for energy storage system.

2) Promote R&D in technology for sustainable and continuous solar power generation to create new knowledge and innovation such as solar tiles and energy storage batteries, for example, through funds from Ministry of Energy to academic institutes or other agencies with potential in R&D.

3) Establish a one stop service or website that could link information to relevant agencies with a central agency responsible for permits such as OERC (or OERC central website) to coordinate the databases of various relevant agencies for more convenience and speed in permit application.

4) Develop management system through the process of participation of all sectors, from the people sector producing electricity and relevant government agencies, by arranging for joint meetings to apprehend the problems and obstacles to solar rooftop power generation in order to determine a guideline of joint operation or meeting, probably organized by OERC.

4.5.3 Management, Control, and Supervision

1) Design measures of access to equipment for the general public in terms of prices and technology by providing the public with the opportunity to use solar equipment with lower prices or costs and access to more solar power technology, as well as investment promotion and soft loans.

2) Set up an ad-hoc agency responsible for the control of the installation according to standards through cooperation with Thailand Professional Qualification Institute (Public Organization), Office of the Prime Minister.

3) Review laws, rules, and regulations related to concrete promotion through cooperation with all relevant sectors such as EGAT, responsible for transmission line system, PEA and MEA, responsible for distribution and retail, and

agencies responsible for policies and supervisions of regulations such as EPPO and OERC to jointly review relevant laws, rules, and regulations to reduce redundancies.

4) Arrange for management and control of disposal of solar cells with the cooperation of Department of Industrial Works and Pollution Control Department to set up a pilot plant to dispose solar panels and batteries.

The operations in all dimensions are interrelated and simultaneous.

4.6 Results of the Implementation Test of the Model to Promote Solar Rooftop Power Generation in Thailand

The results of the implementation test of the model to promote solar rooftop power generation in Thailand by experts from five agencies are shown with the following details:

1) Electricity Generating Authority of Thailand

(1) The model was congruent with current power generation that promoted the use of renewable energy. With appropriate technological development, solar rooftop power generation could reduce peak loads with more efficient power generation.

(2) Some processes might require time to develop supporting technology or increase efficiency in production and management and rely on the drive from the government to promote solar rooftop power generation.

(3) Increase the control of the standards for the installation of solar rooftop and determine the pricing of excess electricity purchasing according to the regulations of excess electricity sale in the grid code.

2) Metropolitan Electricity Authority

(1) The model was congruent with the current promotion of the use of alternative energy according to the government policy and the Power Development Plan 2015-2036.

(2) The implementation of the model must be supported by government policy.

3) Provincial Electricity Authority

(1) The model was congruent with the promotion of solar rooftop power generation.

(2) If management system was put in place such as smart grid, it would enhance efficiency of the country's overall electricity system.

4) EPPO, Ministry of Energy

(1) The model has a congruence, linkage, and high feasibility.

(2) If the model was operated, it would generate efficiency and effectiveness of the operation.

(3) The model must have a responsible agency.

5) Private companies who installed rooftop solar panels

(1) The model must add the channels of public relations and access for the people sector in providing necessary equipment such as solar panels, invertors, and other cheap equipment with standards and under the control and supervision of government agencies.

(2) The model should determine the timeframe and goals in each phase for the project's clear achievement.

(3) Joint agreement with related agencies such as ERC, PEA, MEA, and other related agencies should be carried out where it is crucial that the main relevant agencies understand the criteria so that the enhancement in the private or the public sectors would be effective.

(4) To maximize the efficiency of the use of the model, policy and planning should be formulated in accordance with the 20-Year National Strategy on Energy, Power Development Plan 2015-2036, or other related plans.

The draft model was acquired from the study and the model passed assessment and comments from experts as shown in Table 4.9.

Table 4.9 Draft Model Acquired from the Study Compared with the Model that Passed Assessment and Comments from Experts

Model acquired from the study	Addition from investigation of quality by experts
Policy	
1.1 Formulate action plan according to the policy framework of promotion of solar rooftop power generation through participation process of stakeholders	1.1 Formulate action plan according to the policy framework of promotion of solar rooftop power generation through participation process of stakeholders (EGAT, PEA, MEA, government agencies responsible for policy formulation, SPP)
1.2 Establish a clear process of power generation for own use or power purchase/sale among themselves under supervision of government agencies	1.2 Establish a clear process of power generation for own use or power purchase/sale among themselves under supervision of government agencies
Promotion	
2.1 Establish Memorandum of Agreement between related agencies	2.1 Establish Memorandum of Agreement of related agencies
2.2 Establish subdivision for research and development of technology on sustainable and continuous solar power generation	2.2 Establish subdivision for research and development of technology on sustainable and continuous solar power generation
2.3 Establish center for information and one stop service for solar rooftop power generation	2.3 Establish center for information and one stop service for solar rooftop power generation with coordinating agencies responsible for permits such as OERC (or OERC central website)

Model acquired from the study	Addition from investigation of quality by experts
2.4 Develop management system through participation process of all sectors	2.4 Develop management system through participation process of all sectors. Meetings held by OERC to apprehend problems and obstacles in order to jointly determine operation
Management and supervision	
3.1 Determine measures for the public's access to solar rooftop power generation equipment	3.1 Determine measures for the public's access to solar rooftop power generation equipment
3.2 Establish ad-hoc agency responsible for control of installation to meet the standards through coordination with Thailand Professional Qualification Institute	3.2 Establish ad-hoc agency responsible for control of installation to meet the standards through coordination with Thailand Professional Qualification Institute
3.3 Review laws, regulations, and requirements related to concrete promotion of solar rooftop power generation	3.3 Review laws, regulations, and requirements related to concrete promotion of solar rooftop power generation (relevant agencies, namely: EGAT, PEA, MEA, DEDE, EPPO, ERC, DIW, PCD)
3.4 Establish agency for management and control of disposal of solar panel waste	3.4 Establish agency for management and control of disposal of solar panel waste (with cooperation of Department of Industrial Works and Pollution Control Department)

The experts commented additionally that the draft model could efficiently lead to the promotion of solar rooftop power generation but might need time and the government policy to drive it. Cooperation and integrated work between relevant agencies must also be sought.

CHAPTER 5

CONCLUSIONS

5.1 Conclusions

This study investigated the factors promoting the solar rooftop power generation at present by conducting data analysis with the Delphi technique in three rounds, and studied the growth of informal solar energy to collect data to be used for analysis and construction of the model to promote solar rooftop power generation in the future. This may lead to promotion of efficient solar rooftop power generation and increase alternative energy sources and energy security for Thailand. The findings were as follows:

5.2.1 Factors Promoting Solar Rooftop Power Generation at Present

The study of the factors impacting solar rooftop power generation in Thailand underwent data analysis based on the CIPP-I Model framework as follows:

Context: The factors promoting solar rooftop power generation included the following: Demand for electricity in urban areas/growth of cities and towns/urban population. Urban society was equipped with a large number of utilities to facilitate livelihood which require electricity. Solar rooftop power generation could respond to the demand for electricity in urban areas. Concurrently, urban communities have experienced increasing growth and expansion. A cost-saving alternative for the current urban residents was the installation of solar rooftop. More and more housing estate businesses have turned to installation of solar rooftop. Moreover, there was a tendency for solar power generation technology to become cheaper, stimulating the public demand. There was also opposition to new power plants. Due to demand for electricity and current opposition to new power plants, solar power generation could be an alternative to reduce power plant construction. Solar power generation could respond to the needs for electricity during periods of peak demand. It was also a clean energy source with low impact on environment as recognized by the public. If the prices of solar equipment were lower, they would attract more interest. National Science and Technology Development Agency (NSTDA) has conducted research on production of batteries with low costs for own use of energy storage. In addition, the Federation of Thai Industries in collaboration with Thailand Development Research Institute conducted a study of appropriateness and recommended a guideline to promote the country's grid energy storage (Thailand Development Research Institute, 2019). Regarding exposure to sunlight, Thailand's location in the tropical zone near the equator enhances its rich exposure to sunlight. Thailand is exposed to sunlight at an annual average of approximately 4-5 kilowatts-hour/square meter/day (Phatiphat ThounThong, 2009). If the area receiving sunlight was adapted to follow sunlight at all times and if solar panels were installed at the angle of approximately 10-18 degree with the earth, it was expected to receive approximately 1.3-1.5 times more sunlight. Solar rooftop power generation could therefore be done efficiently and could well reduce the peak demand for electricity in summer (peak period). The clear goal was also determined for production of renewable energy and alternative energy in AEDP each year such as determination of the goal to increase formal solar energy production capacity to 100 MW a year. There was also follow-up on the progress of actual installation and actual power supply. The appropriate investment promotion policy (BOI) and improved regulations and amended laws were in accordance with the context of the installation by reducing redundancies and complications in permit application. Moreover, there was one stop service for services and incentives such as tax reduction for installers.

Input: The factors promoting solar rooftop power generation included the following: Social innovation/awareness/understanding. At present, the public was aware of the importance of energy-saving and use of energy having low impact on the environment. Solar energy technology was therefore an alternative for energy as it was recognized as uncomplicated and easy to understand. Presently, energy-saving innovation included water heating systems with hybrid solar energy and solar roof tiles. Solar power generation could therefore be applied to various functions. People would also like to participate in power generation for their own use or sale to EGAT. Solar rooftop power generation could reduce household electricity costs. If electricity was sold into EGAT's system or on grid, it would generate income for households. If the prices of solar equipment were not high, they would be more accessible. At the same time, the equipment must have quality assurance both in efficiency and safety. If consumers could check the standards of equipment themselves, it would provide them with confidence that every piece of equipment had standard certification. With the problem of installation that did not meet the standards, in the future, if the installers had certification for installation, it would attract more interest.

Process: The factors promoting solar rooftop power generation included the following: Smart grid system for energy management to control electricity stability. Energy storage system was developed for efficiency and low prices. MEA/PEA facilitation of smart grid would promote increased solar power generation as it was possible to see the overall use and lay down the transmission line system that covered the areas in need. EGAT could reduce the power ripple produced from alternative energy. Solar rooftop power generation into EGAT's grid would affect stability or regularity or power ripple such as surges caused by bright sunlight alternating with dips resulting from lack of sunshine. With the use of electricity in high volume, there would be a drop which might affect the efficient use of electricity in some areas. The promotion of power generation from alternative energy should therefore be done in parallel with the development of smart grid system for efficient management of electricity produced from solar energy. Data processing through work control system to control the quality of electric power would ensure that the power supply had correct and regular voltage and electric current, pure electric wave, and correct frequency. Because power supply of low quality would cause energy loss, damage, and mistakes in functioning of various electric devices, it was therefore necessary to have data processing for investigation and conditioning to control quality. It would quickly resolve such issues as they arise in the system, creating stability to the areas around the solar rooftop installation.

Product: The factors promoting solar rooftop power generation included the following: Amplification of solar electricity production. This revealed that the growth of the solar cell and solar panel manufacturing industry in Thailand would give the public more opportunity for access installation. Competition and the market mechanism could increase the share of renewable energy with the installed capacity of electricity from renewable energy 11,852 megawatts or up 4.2% from 2018 (Department of Alternative Energy Development and Efficiency, 2019). As solar energy was environmental-friendly with no cost for purchase of fuel which will be depleted in the future, more people would be interested in solar rooftop power generation. The areas for power generation also increased as solar energy could be produced in all areas of Thailand. Solar energy potential depended on total radiation intensity from the sun per area. The consideration of the total radiation intensity on the average a day per year through the average of all the areas nationwide revealed that the intensity equaled 18.0 MJ/m2-day or 5.0 kWh/m2-day (Department of Alternative Energy Development and Efficiency, 2017a). Consequently, people in remote areas could have access to electricity. There was consumption of power generated in the areas which was considered the optimal use of power (wherever there was power consumption, there was power generation). Moreover, with solar rooftop power generation in the areas with electricity needs, it would reduce energy loss in the transmission line system.

Impact: The factors promoting solar rooftop power generation were divided into three dimensions: 1) Economic: It constituted to economic growth. Solar power generation entailed investment in renewable energy, leading to the growth of solar energy industry, and enabling the public to install solar power generation systems on a wide scale. 2) Social: It reduced the needs for new power plants. As solar power generation could respond to the public’s electricity demand, there was no need to construct new power plants (coal-fired power plant). It also increased employment. Solar power generation could increase employment on a wide scale. For example, solar rooftop power generation in Bangladesh generated employment and stimulated the local economy by installing solar home systems for 3.6 million households, generating direct employment of 115,000 positions and over 50,000 positions of indirect employment (Tara Buakamsri, 2019). As for Thailand, according to the Department of Industrial Works, in January 2020, the employment rate in solar power generation constituted 1.5% per power generation of 1 MW (National Institute of Development Administration, 2020). Solar power generation also enhanced energy security, reduced import of energy and fuel used in power generation, and provided diverse alternatives in energy consumption. As solar energy was clean, it had a low impact on the environment. Solar power generation therefore created good environment and promoted the image of energy consumption, internationally appreciated and recognized. 3) Environmental: Solar energy was the energy accessible to all and solar power generation could reduce GHG emission. Solar power production capacity of 1 MW could reduce GHG emission by approximately 1,000 tCO_2e/year (Thailand Greenhouse Gas Management Organization, 2011). Solar rooftop power generation was therefore the use of renewable energy found everywhere for maximum benefit.

5.2.2 Expansion of Solar Electricity not Registered with Government Agencies

The study of the expansion of solar power generation from the trade database of Ministry of Commerce and Customs Department between 2002-2019 showed that Thailand had a large solar power production capacity with a cumulative production capacity of 46,478 MW. The analysis to forecast capacity with the Quadratic polynomial equation revealed that generation tended to increase production capacity in the future. The equation could be used to forecast solar power generation such as variable substitution of X = Number of years of import of solar panels in order to forecast Y = Import volume of solar panels in the equation. The government or relevant agencies could use the equation to prepare policy to promote solar power generation, develop efficient network system to control electricity stability in order to accommodate power generation from renewable energy, as well as motivating power producers to register solar power generation. At present, the registration of the formal solar power generation contributed to 2,935.019 MW This It would lead to the accurate data on the actual installed capacity of solar power generation. The information could also be used to construct a model for disposal of solar panel waste.

5.2.3 Model Promoting Future Solar Power Generation

The SWOT analysis consisted of the following:

Strengths: The general public could understand the use of solar power easily due to its simple technology, cheaper solar power equipment, application of solar rooftop technology in diverse forms of social innovation (social innovation means method, principle, concept required by society, and application to quality of life such as use of solar energy for water pumping in agriculture to benefit communities), expansion of solar power production capacity, reduction of import of fuel and purchase of electricity from abroad, increase of areas for power production in response to the needs of power consumption across the country, reduction of power loss in the transmission system, household participation in power generation, and public relations via media to campaign for energy saving and increased use of renewable energy.

Weaknesses: No standards of professional qualifications were yet established for installers of power generation system from solar rooftop. The equipment was cheaper but not all groups had access while the current purchasing prices of electricity were very much lower. Moreover, solar rooftop could generate electricity during daytime and there must be the system to control electricity stability and energy storage for electricity use during the night, power ripple/fluctuation (surge/drop), and compilation of data/data processing/system self-correction. However, at present, the installation of solar rooftop did not provide sufficient incentives through lack of readiness to facilitate smart grid of MEA and PEA. The permit application required many processes. There was no clear agency responsible for disposal of solar panel waste. Moreover, solar rooftop could generate electricity only during the daytime.

Opportunities: Solar power generation reduced the demand for new power plants and could create energy security/diversification in energy use. As the AEDP/policy on the promotion of solar power generation were put in place, solar power generation would contribute to economic growth and increase employment in response to the demand for electricity in urban areas/growth of cities and towns/urban populations, and address the problem of opposition to new power plants as solar power generation was accepted by the public. At present, the costs of renewable energy tended to decrease. Technological advancement also rendered solar power generation efficient. Solar rooftop technology has a small impact on the environment. Thailand is sufficiently exposed to sunlight required for solar rooftop power generation, enhancing good image/clean environment.

Obstacles: Policy to promote renewable energy lacked continuity. The cost of the installation was high. The knowledge of the public on the promotion of solar rooftop power generation was not widespread and needed to develop/prepare energy storage system. There were many related laws and regulations causing confusion in permit applications. There was also the problem of irregular exposure to sunlight (during periods when the sunlight was hidden by clouds).

5.2 Model Promoting Future Solar Rooftop Power Generation

The model to promote future solar rooftop power generation underwent analysis and synthesis of data through SWOT analysis and TOWS Matrix. The analysis of the policies, strategies, and plans related to promoting solar rooftop power generation was under item 4.1. The study of the factors promoting solar rooftop power generation was under item 4.2. The analysis of the expansion of informal solar power was under item 4.3. Therefore, the model could be summarized as follows:

5.2.1 Policy

1) Formulate action plan according to the policy framework promoting solar rooftop power generation through participation process of stakeholders based on the result of the analysis of the factors promoting solar rooftop power generation and the result of the analysis of the expansion of informal solar power generation due to the complicated permit application process that involved many agencies, posing obstacles to installers. Relevant agencies should integrate their operation and stakeholders should be provided the opportunity to take part in formulating operation.

2) Establish clear process of power generation for own use or power purchase/sale among themselves under supervision of government agencies. The amount of informal power production capacity showed that a great deal of solar energy producers did not register. The analysis of the overall policy revealed that in the future the government would promote more solar rooftop power generation for own consumption. The process of power generation for own consumption should be

established as well as clear process of purchase/sale of electricity to ensure order and common recognition to manage the country's electricity production and consumption.

5.2.2 Promotion

1) Establish Memorandum of Agreement among agencies related would impact the quality of electricity in the system and the fluctuation of electric system, due to the large amount of installed capacity of informal solar power generation. The promotion of increased consumption of renewable energy would require the development and improvement of transmission and distribution systems of grid modernization to address the problems of quality of electricity and encourage concrete cooperation. Therefore, a Memorandum of Agreement should be established between EGAT, PEA, and MEA.

2) Establish subdivision for R&D of technology on sustainable and continuous solar power generation. The research result revealed that the development of efficient solar power generation technology was important and motivated solar rooftop power generation. For example, research to develop the efficiency and lower costs of energy storage batteries, and the development of solar cells that could generate more electricity but with lower costs could motivate and create price mechanisms that increased accessibility to the general public.

3) Establish center of information and one stop service of solar rooftop power generation. The study revealed that the process of permit application involved many agencies, causing confusion in the process in terms of coordination and submission of documents. Public relations of news and information on solar power generation were also relatively limited. There was no clear responsible agency to respond to the policy and plan to promote the consumption of renewable energy. In order to address these problems and accommodate the general public, one stop service should be established to facilitate the public relations and permit application process, reduce time and process, and also jointly use the database of power producers from solar rooftop, resulting in effective management and analysis of the overall situation of power generation.

4) Develop management system of solar rooftop power generation through participation process of all sectors. The study result revealed that the

participation of stakeholders was important, especially the participation of households. Therefore, an office should be established for development of management of solar rooftop power generation for exchanges of information, demand, and limitations that constituted problems and obstacles between related agencies and stakeholders.

5.2.3 Management and Supervision

1) Determine the measures for the public's access to solar rooftop power generation equipment. The study result revealed that cheaper equipment would attract more people to solar power generation. At the same time, advanced solar energy technology could serve as an efficient alternative for power generation at present. The measure should therefore be formulated to have access to the equipment to ensure access by all groups.

2) Establish an ad-hoc agency responsible for control of installation of system of solar rooftop power generation to meet the standards through coordination with Thailand Professional Qualification Institute. The research result revealed that the certification of the standards of equipment/skill training for the installation were important factors to promote solar rooftop power generation. An ad-hoc agency should therefore be founded to control and ensure that the installation would meet the standards to enhance credibility and recognition of solar power generation as well as accommodate the growth of the solar energy industry.

3) Review laws, regulations, and requirements related to concrete promotion of solar rooftop power generation The research result found that relevant laws/regulations played a major role. Therefore, laws, rules, and regulations should be concretely reviewed to reduce redundancies in operation and result in integrated operation among different agencies.

4) Establish a management agency to control of disposal of solar panel waste. The study result of the expansion of informal solar power generation revealed that the growth rate was on the average 37% a year. As a result, the plan must be formulated to address waste management. An agency should therefore be founded to manage and control the disposal of solar panel waste to ensure management of the entire life cycle of products.

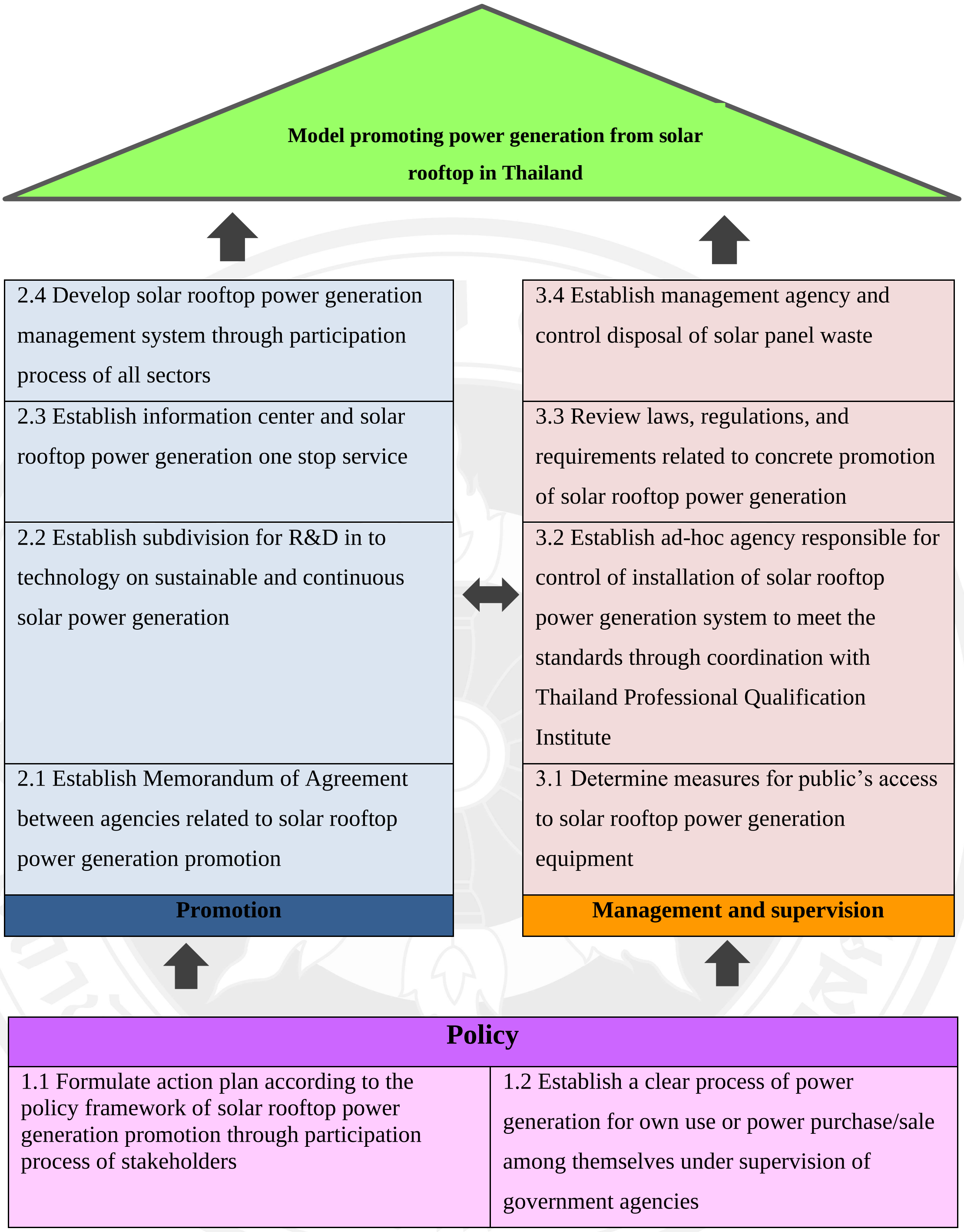

Figure 5.1 Model of Solar Rooftop Power Generation Promotion in Thailand

5.3 Discussions

5.3.1 Factors Promoting Solar Rooftop Power Generation at Present

For solar rooftop power generation promotion in Thailand to be efficient and able to reach the goal of the promotion, the following factors of promotion are required:

Context: Hamilton, White, Lammers, and Myerchin (2012) analyzed the relationships between the population, communities, and climates for the use of electricity in the Arctic. It was found that the population living in different climates consumed electricity differently. This was in line with Thailand which has a hot climate and thus a large amount of electricity consumption. Ansolabehere and Konisky (2009) studied the public's attitude toward construction of new power plants as the US needed to construct hundreds of new power plants. They found that the US population opposed construction of power plants from coal, and natural gas, as well as nuclear power plants due to impact on environment and health. O'shaughnessy and Margolis (2018) studied of market value of solar energy and found that the prices for system installation in residential areas had decreased tremendously over the past years but only some groups of customers had access to it. The pricing of system installation was therefore crucial. Moreover, Ninsawat and Hossain (2016) revealed that the exposure to sunlight influenced the volume of power generation. These factors affected the ability to generate solar power in particular areas. These were in line with Jung and Tyner (2014) who studied the economic and policy analysis of solar power systems in Indiana. They revealed that the government formulated efficient policy on alternative energy for promotion of solar power system. This led to the successful promotion of solar power generation. Incentives were also put in place to attract more solar rooftop power generation.

Input: The factors promoting solar rooftop power generation included the following. Solar energy was a social innovation that could be applied to various tasks. People realized and understood the use of alternative energy. This was in accordance with Levison and Oehme (2017) who studied the social acceptance of solar energy technology in Kenya. They found that the use of solar energy technology to produce electricity in coffee plantation was an innovation that farmers understood and accepted, creating households' participation in energy preservation (Clastres, Ha Pham, Wurtz,

& Bacha, 2010), resulting in more demand for the use of solar energy technology in power generation, as well as households' demand for participation in solar rooftop power generation. If the prices of solar equipment were not high and if the equipment had quality assurance, it would foster more confidence in solar rooftop power generation. Moreover, the equipment and the system installers were important. If the solar equipment had standard certification and if the installers attended skill training on system installation with certification, they would receive more recognition for solar power generation through the installation of systems based on standards and safety (Hoke et al., 2018)

Process: The factors promoting solar rooftop power generation included the following. System to control electricity stability and development of good energy storage system, ability to reduce power ripple/fluctuation (surge/drop)/data collection, electricity quality in the system through work control system/data processing to control the quality of electric power to ensure that the supply had correct and regular voltage and electric current/system self-correction. This was in line with Jarmakiewicz, Parobczak, and Maślanka (2017) who studied the control of electricity standards. They found that the control of electricity standards was important to the safety of the system and it was the factor that should be considered in power generation. The promotion of solar power generation would be more sustainable if MEA and PEA could facilitate smart grid. This was in line with Cardenas et al. (2017) who studied the ability of power generation in various countries. They found that if there was readiness in smart grid, the system of solar power generation could be installed in all areas in a country.

Product/Outcome: The factors promoting solar rooftop power generation included the following. Increased solar rooftop power generation would expand solar power generation, reduce import of fuel and purchase of electricity from abroad, increase share of renewable energy, increase the areas for power generation in the system, and reduce power loss in the transmission line system. This was in line with Greulich, Höffler, Würfel, and Rein (2013) who studied the factors of solar rooftop power generation, including the ability to increase the share of renewable energy, increase the areas for power generation in the system, and reduce power loss in the system.

Impact: The factors promoting solar rooftop power generation were divided into three dimensions. 1) Economic: Solar rooftop power generation constituted economic growth. 2) Social: Solar rooftop power generation could reduce demand for new power plant and increase employment. In Thailand, the direct employment rate was the number of positions per power generation of one million units (or 1 GWh). The employment rate in the field of solar energy was 0.766 positions per power generation of one million units a year (Greenpeace Thailand, 2018). This was in accordance with Zhang, Chen, Liu, Yang, and Xu (2017) who studied the employment rate of the solar energy industry. They found that the solar energy industry increased employment, resulting in economic growth, energy security, increased alternative use of energy for more diversification, and good image as it had low environmental impact. Thus, it was considered a clean energy source, recognized and widely used by the public. 3) Environmental: Solar power generation made use of sunlight found everywhere to produce electricity for daily life. Thus, it was considered clean energy, recognized and widely used by the public.

5.3.2 Expansion of Solar Power not Registered with Government Agencies

The researcher studied the import of solar cells in Thailand (trade database of Ministry of Commerce and Customs Department between 2002-2019) and found that Thailand had the cumulative installed capacity totaling 46,478 MW with those registered for formal solar power generation totaling 2,935.019 MW (Office of Energy Regulatory Commission, 2020). The export of solar cells between 2007-2019 totaled 2,315.98 MW (Customs Department, 2020a). Thus, the informal solar power totaled 41,227.001 MW. This showed that there was a significant amount of informal solar power generation or informal solar electricity with no official report. This also showed that a large amount of solar energy technology was used in Thailand both in terms of power generation and heat. In 2019, solar power generation totaled 5,145.9 million kilowatts and the use of solar energy for heating equaled 425,820 GJ (Department of Alternative Energy Development and Efficiency, 2019). The use of solar cells in tools and appliances included solar power lamp, solar cell water pump, and solar cell spotlight.

However, if the actual volume of power generation was unknown, it would be difficult to forecast the actual demand for electricity. This would lead to formulation of plans and policies not in accordance with the country’s energy situation and might encounter a reverse electric current back into EGAT’s system, impacting efficiency of EGAT’s energy management. On the promotion of solar power generation, apart from clear, concrete promotion policy, responsible agencies are needed for effective coordination of promotion cooperation among agencies.

The disadvantage of solar rooftop power generation promotion included the limitation in transmission line system and lack of readiness in data collection, and data processing causing fluctuations in the power system. EGAT should improve, develop, and use modern technology in parallel with planning to develop an electricity system that reduces technical impact on the power system. For example, a data monitoring system by electric meters would be a major mechanism to collect solar power generation data from all the systems connected to EGAT. This could be undertaken in parallel with the formulation of promotion policy in order for MEA and PEA to be able to plan and improve distribution systems and for EPPO and EGAT to be able to make forecasts of the demand for electricity and management of system load curve, resulting in Thailand’s power development plan and development of smart grid as appropriate in the future. The lack of the stipulation of standards to organize the business sector who install solar rooftop power generation systems resulted in faulty transmission line system of MEA/PEA, impacting electricity users in surrounding areas. As the processes for permit application were complicated, many installers did not register or participate in various projects with the government agencies.

5.3.3 SWOT analysis of Solar Rooftop Power Generation Promotion from the Study is as Follows.

Strengths: Solar rooftop technology could be applied to various forms of social innovation (social innovation means method, principle, concept in demand in society that benefits people's quality of life such as use of solar energy for pumping in agriculture to benefit communities). This in accordance with Pimonmart Wankanapon, Anake Suwanchaiskul, Parinee Srisuwan, and Chalermwat Tantasavasdi (2012) who conducted a case study of the benefit of the use of solar panel in low cost residential buildings. It was found that the installation of solar panels of 2.22 kW could generate electricity 5.48 kWh/day to accommodate the demand for electricity for wastewater treatment machine using electricity for an average of 2.10 kWh/day and reduce heat under the roof on which the solar panels were installed. This would lead to expansion of solar power generation, reduce the import of fuel and purchase of electricity from abroad, increase the share of renewable energy, increase the areas of energy production in response to energy consumption demand in various areas across the country. This was in accordance with Kurdgelashvili et al. (2016) who estimated the technical potential for rooftop photovoltaics in California, Arizona, and New Jersey and revealed that the potential of solar rooftop power generation in the three states equaled 35%, 43%, and 61%, respectively of the demand for electricity consumption and could increase the present production capacity 20 fold, 30 fold, and 40 fold, respectively. This estimate showed the potential for significant growth of PV and the reduction of power loss in the transmission system.

Weaknesses: Although solar energy equipment was cheaper, not all groups had access at these prices. At the same time, at present, pricing of electricity purchase was much lower than in the past. For example, in the past, the purchasing prices for solar rooftop power generation in the form of FiT ranged between 6.16-6.96 baht depending of the size of installation (King Mongkut's University of Technology Thonburi, 2016). However, at present, the purchasing price for solar rooftop power generation which was excess electricity from residences under the project of solar energy for the general public was 2.20 baht/kWh (Energy news center, 2020). Moreover, solar rooftop could generate electricity only during the daytime. This was in accordance with Pairote Thongprasri (2018) who analyzed the relationship between solar power and rated load for installation of stand-alone PV system. The research investigated the relation between electric power produced from solar energy during one day to determine the range of the installed solar cells that were appropriate to the load of function during the determined time. At present, the installation of solar rooftop did not offer sufficient incentives. This was in line with a study into the scaling up of solar PV in Thailand (Chulalongkorn University, 2015) which found that marketing incentives for system installation would reach the goal of solar power generation, reduce costs, and encourage participation by the general public. The lack of readiness in terms of facilitation of smart grid by MEA and PEA, and permit application process were important for the decision to install solar rooftop.

Opportunities: Solar power generation could reduce the demand for new power plants, foster energy security leading to economic growth and increased employment in response to the demand for electricity in urban areas. Jo et al. (2010) investigated sustainable urban energy by developing a mesoscale assessment model for solar reflective roof technologies and revealed that solar rooftop power generation could reduce peak demand for electricity in the studied cities, and could reduce GHG emissions, benefiting the environment. Presently, the costs of renewable energy has tended to decrease. Technological advancement also ensured efficient solar power generation. The Annual Energy Outlook 2019 by Energy Information Agency (EIA) constructed the scenario until 2050 and forecast that power production capacity in buildings and residences would increase reflecting reduced costs in technology and the continuity of motivation for solar energy technology across sectors (Capuano, 2019) due to its low environmental impact. Wirut Pichitkunchorn and Keerati Chayakulkheeree (2018) investigated the design and analyzed of cost effectiveness of system installation of solar rooftop power generation on the building of Post Engineer Department, Royal Thai Army of 25 kW. They revealed that the produced electricity equaled 34,809 units a month and saved approximately 1,670,832 baht a year, and could reduce GHG emission into the atmosphere by 225.56 tons CO_2 equivalent a year. As Thailand is sufficiently exposed to sunlight, this resulted in efficient solar rooftop power generation.

Obstacles: Lack of continuity in the policy to promote renewable energy. Disorn Chaichuangchok, Sopitsuda Tongsopit, and Naebboon Hoonchareon (2013) studied the model of the financial measures appropriate to support the solar rooftop power generation system in Thailand. They stated that the installation in Thailand still lacked support from the government, no clear measures to attract people' s interest in the installation, costs for installation were expensive, and readiness was yet to be developed for energy storage system. Energy storage system was an important tool that would enhance efficiency in power generation from renewable energy and ensure that the distributed power generation and clean energy were more stable but with higher prices. Although the prices of energy storage system tended to decrease, the prices were remained high. The initial investment still required government support or soft loans (Ministry of Energy, 2019). Moreover, many relevant laws and regulations such as Energy Industry Act B.E. 2550 (2007) and Town Planning Act B.E. 2518 (1975) posed compliance complications in terms of permit application.

5.3.4 Model of Future Solar Rooftop Power Generation Promotion

This study conducted an analysis of the policies, plans, strategies, and factors promoting solar power generation, as well as the growth of informal solar power generation with an average increase of 37% a year. In the past, the Ministry of Energy's solar power generation promotion was done through loans and investment promotion in the solar power industry (BOI), grants for solar power projects, and policy to purchase solar power in various forms. The study of Chutima Yudee and Sthianrapab Naluang (2019) on the legal measures to promote solar power generation revealed that there was no clear legal measure to promote the production and the use of solar power in terms of production, sale, and the uncertain government's policy with discontinuity and change according to the policy of the government in each era. There was also lack of unity in policy management as there were many involved agencies so the law and policy could not serve as a tool to promote and utilize the country's solar power to achieve progress. This research recommended the amendment of the law and improvement of the government's policy on the promotion of production and use of solar power. For example, the Town Planning Act B.E. 2518 (1975) should determine the overall town planning of each province with the same standards, one additional area for the land use of solar energy, the share of public utilities, facilities, or local empowerment to enact laws on the promotion of the use of renewable energy in the rural areas, among other recommendations. The research of Phimsupha Kokchang and Siripha Junlakarn (2019) of the Energy Research Institute, Chulalongkorn University, argued that more installation of solar rooftop system for power generation and for own use would lead to purchase/sale of electricity where the public could be both buyers and sellers and could make electricity transactions among themselves through peer-to-peer energy trading which many countries had already operated as pilot projects.

The promotion of solar rooftop power generation model could be used from formulation of policy and strategy to encourage entrepreneurs and installers of solar rooftop to install and promote solar rooftop power generation in all areas in Thailand, to increase management and supervision efficiency from the first until the last process of the operation. These forged sustainability in the promotion of solar rooftop power generation in line with the Strategies of Ministry of Energy 2018-2022 in Strategy 3: Development of sustainable and environmental-friendly energy, Goal 2: Increased share of production and use of alternative energy, and Goal 3: Communities are self-reliant in development of energy to respond to the needs according to the potential of areas (Ministry of Energy, 2021).

5.4 Recommendations

5.4.1 Utilization of Research

1) Policy

(1) Apply the results of the factors of solar rooftop power generation promotion to the formulation of the government's measures to encourage the public to produce power from solar rooftop.

(2) Use the results of the expansion of solar power to forecast the future expansion and formulation of the plan to accommodate solar rooftop power generation in the management of raw materials used for production and waste from solar panels, as well as electricity prices.

2) Implementation

(1) Use the results of the future growth of solar power to plan for the search and construction of the location for disposal of solar panel waste.

(2) Apply the model of solar rooftop power generation promotion to community networks interested in solar rooftop power generation in other areas nationwide.

5.4.2 Future Research

1) Study should be conducted on the standards of the system installation of power from solar rooftop in accordance with EGAT's system in Thailand.

2) Study should be conducted on the model and method appropriate to solar rooftop power generation for the public's own use in Thailand in order to motivate and increase the public's interest in solar rooftop power generation.

3) Study incentives to install power generation system from solar rooftop such as tax measures.

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APPENDICES

Appendix A

Open-ended Interviews with Experts

Delphi

Round One

Open-ended interviews with experts. The questions were summarized into the following issues:

1. What do you consider of the current promotion of solar rooftop? Should the public sector support the installation of solar rooftop?

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2. Can Thailand use the solar cell technology efficiently, covering all areas?

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3. What is your view of regulations of solar rooftop installation?

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4. How do you consider the installation of solar rooftop in terms of the positive and negative impacts on power consumers, the society, and the country?

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5. Will you install solar rooftop? Why or why not?

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6. Do you consider the technology for solar rooftop power generation to be appropriate for current power generation? Does the operation pose difficulties or not?

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7. Do you consider the grid system of MEA and PEA to be ready for solar rooftop power generation?

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8. Should EGAT improve the system or how should EGAT prepare for power generation from renewable energy?

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9. Do you consider that the license request for the current solar rooftop power generation project entails any problems and obstacles? How?

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10. What are the factors that can motivate you to produce power from solar rooftop?

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Round 1 The issues were summarized using open ended interviews.

Factors of promotion of power generation from solar rooftop in Thailand

Issues	experts																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Context																			
1. Demand for electricity in urban areas/urban growth/population in urban areas					√	√	√		√	√		√		√	√	√	√		
2. Electricity prices/oil prices					√										√				
3. Opposition to construct new power plant		√	√			√	√				√				√	√	√		
4. Equipment for solar energy is cheaper/technological advancement		√	√								√							√	
5. Reception of sunlight	√							√							√			√	√
6.AEDP/policy/law/ regulations/ incentives			√		√	√	√										√	√	√
Input																			
1. Social innovation/awareness/understanding			√			√	√								√		√	√	
2. Participation from households				√		√				√					√				
3. Supply of solar energy equipment/ quality assurance of equipment				√				√		√	√				√		√		
4. Standard certification of equipment/ training for skill in installation	√		√							√	√						√		√

Issues	experts																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Process																			
1. System to control electricity stability/energy storage system											√				√	√	√		
2. Accommodations of Smart Grid of MEA and PEA			√	√		√				√	√	√			√		√		
3. Current ripple/fluctuation (power surge/brownout)/data compilation/data processing/system of self-rectification				√			√	√		√									
Product/Outcome																			
1. Expansion of power generation from solar energy				√			√		√	√	√	√		√	√	√	√		√
2. Increase share of renewable energy		√	√			√									√		√	√	
3. Increase efficiency in power generation		√	√	√			√	√		√					√				
4. Reduce energy loss in the system														√	√				
Impact																			
1. Economic growth		√					√			√		√	√		√				√
2. Ability to reduce demand of new power plant							√								√	√	√		
3. Increase in employment						√	√				√				√		√	√	
4. Energy security/diversity			√				√	√							√			√	
5. Creation of good image /clean environment / people's appreciation/ recognition			√					√			√								
6. Increase use of domestic resources (solar energy)															√				√

Appendix B

Rating Scale Questionnaire Compiled all Experts' Views of the Questionnaire in Round 1 to Construct the Rating Scale Questionnaire and Returned it to the same Experts

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Delphi

Round Two

Round 2 Rating Scale Questionnaire

Explanation, please put a mark √ in ☐ the answer page you need.

	Issues	Rating Scale 1	2	3	4	5	Note
Context	1. Demand for electricity in urban areas/urban growth/population in urban areas						
	2. Electricity prices/oil prices						
	3. Opposition to construct new power plant						
	4. Equipment for solar energy is cheaper/technological advancement						
	5. Reception of sunlight						
	6. AEDP/policy/law/regulations/ incentives						
Input	1. Social innovation/awareness/understanding						
	2. Participation from households						
	3. Supply of solar energy equipment/ quality assurance of equipment						
	4. Standard certification of equipment/ training for skill in installation						
Process	1. System to control electricity stability/energy storage system						
	2. Accommodations of Smart Grid of MEA and PEA						
	3. Current ripple/fluctuation (power surge/brownout)/data compilation/data processing/system of self-rectification						
Product/ Outcome	1. Expansion of power generation from solar energy						
	2. Increase share of renewable energy						
	3. Increase efficiency in power generation						
	4. Reduce energy loss in the system						
Impact	1. Economic growth						
	2. Ability to reduce demand of new power plant						
	3. Increase in employment						
	4. Energy security/diversity						
	5. Creation of good image /clean environment / people's appreciation/ recognition						
	6. Increase use of domestic resources (solar energy)						

Appendix C

Rating Scale Questionnaire Compiled all Experts' Views of the Questionnaire in Round 2 to Construct the Rating Scale Questionnaire in Round 3 and Returned it to the same Experts

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Delphi

Round Three

Round 3 Rating Scale Questionnaire

Explanation, please put a mark √ in the ☐ answer page you need in round three again. If your answer is inconsistent with experts answer, please specify the reason in the note

Symbol Δ refers to the value of the rating scale that you answer in the 2nd round

Symbol ▭ refers to the median calculated from the entire group of experts

Symbol __ refers to the inter-quartile range calculated from the entire group of experts

	Issues	Rating Scale 1	2	3	4	5	Note
Context	1. Demand for electricity in urban areas/urban growth/population in urban areas					Δ	
	2. Electricity prices/oil prices				Δ		
	3. Opposition to construct new power plant					Δ	
	4. Equipment for solar energy is cheaper/technological advancement				Δ		
	5. Reception of sunlight				Δ		
	6. AEDP/policy/law/regulations/ incentives				Δ		
Input	1. Social innovation/awareness/understanding				Δ		
	2. Participation from households			Δ			
	3. Supply of solar energy equipment/ quality assurance of equipment				Δ		
	4. Standard certification of equipment/ training for skill in installation				Δ		
Process	1. System to control electricity stability/energy storage system				Δ		
	2. Accommodations of Smart Grid of MEA and PEA			Δ			
	3. Current ripple/fluctuation (power surge/brownout)/data compilation/data processing/system of self-rectification			Δ			
Product/ Outcome	1. Expansion of power generation from solar energy				Δ		
	2. Increase share of renewable energy				Δ		
	3. Increase efficiency in power generation			Δ			
	4. Reduce energy loss in the system				Δ		
Impact	1. Economic growth				Δ		
	2. Ability to reduce demand of new power plant				Δ		
	3. Increase in employment				Δ		
	4. Energy security/diversity				Δ		

Issues	Rating Scale					Note
	1	2	3	4	5	
5. Creation of good image /clean environment / people's appreciation/ recognition				Δ		
6. Increase use of domestic resources (solar energy)				Δ		

Appendix D

The Evaluation form of the Draft Model was Given to the Experts from Relevant Agencies for Comments in order to Recommend the Complete Model.

The evaluation form of the draft model to promote power generation from solar rooftop in Thailand

Organization………………………………………………………………………………

Explanation, for experts to consider and criticize, advise and comment to the draft model to promote power generation from solar rooftop in Thailand

Model acquired from the study	Addition from the investigation of quality by experts
Policy	
1.1 Formulate action plan according to the policy framework of promotion of power generation from solar rooftop through participation process of stakeholders	……………………………………………... ……………………………………………... ……………………………………………... ……………………………………………... ……………………………………………...
1.2 Establish the clear process of power generation for own use or power purchase/sale among themselves under the supervision of the government agencies	……………………………………………... ……………………………………………... ……………………………………………... ……………………………………………...
Promotion	
2.1 Establish Memorandum of Agreement of agencies related to promotion of power generation from solar rooftop	……………………………………………... ……………………………………………... ……………………………………………... ……………………………………………...
2.2 Establish subdivision for research and development of technology on sustainable and continuous solar power generation	……………………………………………... ……………………………………………... ……………………………………………... ……………………………………………...

Model acquired from the study	**Addition from the investigation of quality by experts**
2.3 Establish center of information and one stop service of power generation from solar rooftop	………………………………………………... ………………………………………………... ………………………………………………... ………………………………………………...
2.4 Develop management system of power generation from solar rooftop through participation process of all sectors	………………………………………………... ………………………………………………... ………………………………………………... ………………………………………………...
Management and supervision	
3.1 Determine the measures for the public's access to equipment of power generation from solar rooftop	………………………………………………... ………………………………………………... ………………………………………………... ………………………………………………...
3.2 Establish ad-hoc agency responsible for control of installation of system of power generation from solar rooftop to meet the standards through coordination with Thailand Professional Qualification Institute	………………………………………………... ………………………………………………... ………………………………………………... ………………………………………………... ………………………………………………... ………………………………………………... ………………………………………………...
3.3 Review laws, regulations, and requirements related to concrete promotion of power generation from solar rooftop	………………………………………………... ………………………………………………... ………………………………………………... ………………………………………………...

Model acquired from the study	**Addition from the investigation of quality by experts**
3.4 Establish agency of management and control of disposal of solar panel waste	…………………………………………... …………………………………………... …………………………………………... …………………………………………... …………………………………………...

1. The Principle of the model (Linkage and possibilities)

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2. The Efficiency and Effectiveness of the draft model to promote power generation from solar rooftop in Thailand

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3. The application of the model (Guidelines for setting policies or a form of promoting solar rooftop)

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4. Other Comments / Suggestions

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BIOGRAPHY

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ACADEMIC BACKGROUND	Bachelor's Degree with major in Faculty of Social Sciences from Srinakharinwirot University, Bangkok, Thailand in 2011 Master's Degree with major in Environmental Management from National Institute of Development Administration (NIDA), Bangkok, Thailand in 2014
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